FM 5-31

DEPARTMENT OF THE ARMY FIELD MANUAL

BOOBYTRAPS

HEADQUARTERS, DEPARTMENT OF THE ARMY
SEPTEMBER 1965

FIELD MANUAL
No. 5–31

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *14 September 1965*

BOOBYTRAPS

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*This manual supersedes FM 5–31, 31 January 1956, including C 1, 16 December 1957, and C 2, 28 August 1959.

CHAPTER 1

CHARACTERISTICS OF BOOBYTRAPS

Section I. INTRODUCTION

1. Purpose and Scope

a. This manual contains procedures, techniques, and expedients for the instruction of the soldier in the assembly, use, detection, and removal of boobytraps in combat.

b. Included are descriptions and discussions of the design and functioning characteristics of standard demolition items — firing devices, explosives, and accessories — and missiles, such as hand grenades, mortar ammunition, artillery ammunition, and bombs.

c. This manual also contains information on a variety of items and indigenous materials useful for improvising firing devices, explosives, and pyrotechnic mixtures for guerrilla warfare applications.

d. Factory-produced boobytraps (dirty trick devices) are described. Most of these have been developed and used in the field by foreign armies.

e. Safety measures pertinent to boobytrapping operations are provided for the protection of troops from casualty.

f. The contents of this manual are applicable to nuclear and nonnuclear warfare.

2. Comments

Users of this manual are encouraged to forward comments or recommendations for changes for improvement. Comments should be referenced to the page, paragraph, and line of text. The reason for each comment should be given to insure proper interpretation and evaluation. Forward all comments directly to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia 22060.

Section II. PRINCIPLES OF OPERATION

3. Types of Boobytraps

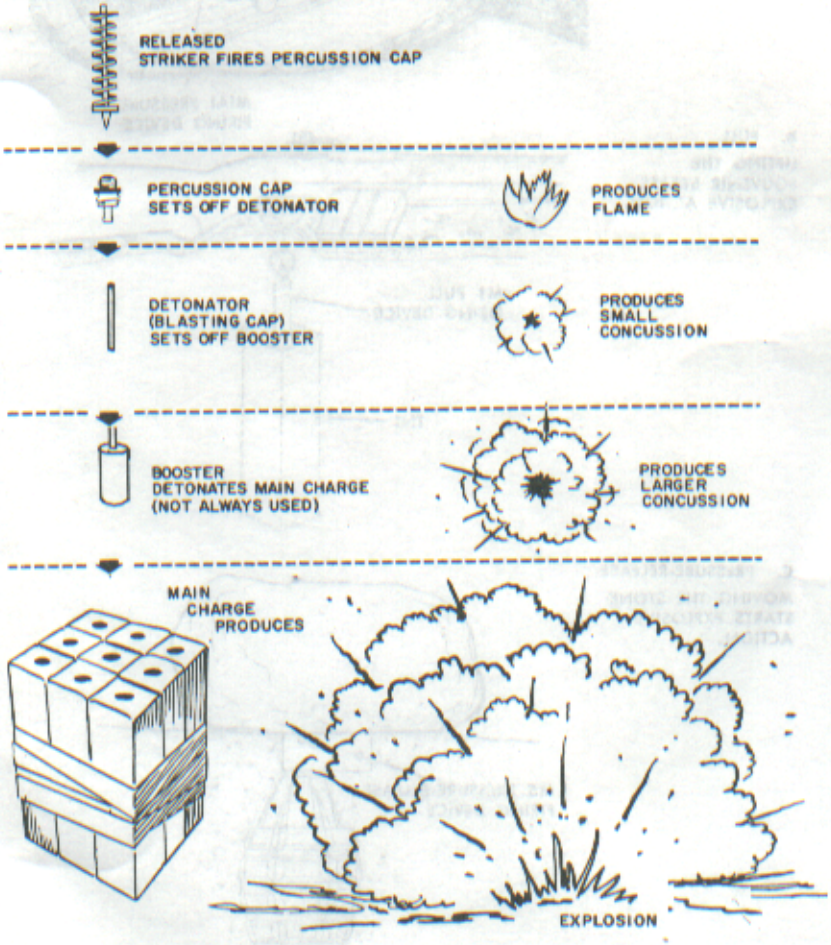
A boobytrap is an explosive charge cunningly contrived to be fired by an unsuspecting person who disturbs an apparently harmless object or performs a presumably safe act. Two types are in use —improvised and manufactured. Improvised boobytraps are assembled from specially provided material or constructed from materials generally used for other purposes. Manfactured boobytraps are dirty trick devices made at a factory for issue to troops. They usually imitate some object or article that has souvenir appeal or that may be used by the target to advantage.

4. Assembling Boobytraps

A boobytrap consists of a main charge, firing device, standard base (not always used), and detonator. Another item, the universal destructor, is an adapter for installing a firing device assembly in a loaded projectile or bomb to make an improvised boobytrap. Also, firing device assemblies are often attached to the main charge by means of a length of detonating cord.

5. Boobytrap Firing Chain

THE FIRING CHAIN IS A SERIES OF INITIATIONS BEGINNING WITH A SMALL QUANTITY OF HIGHLY SENSITIVE EXPLOSIVE AND ENDING WITH A COMPARATIVELY LARGE QUANTITY OF INSENSITIVE EXPLOSIVE.

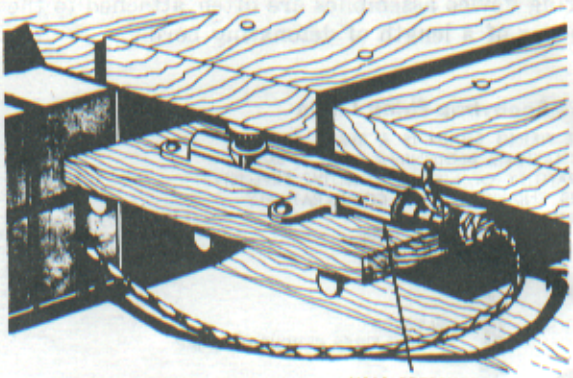


6. Initiating Actions

THE INITIATING ACTION STARTS THE SERIES OF EXPLOSIONS IN THE BOOBYTRAP FIRING CHAIN.

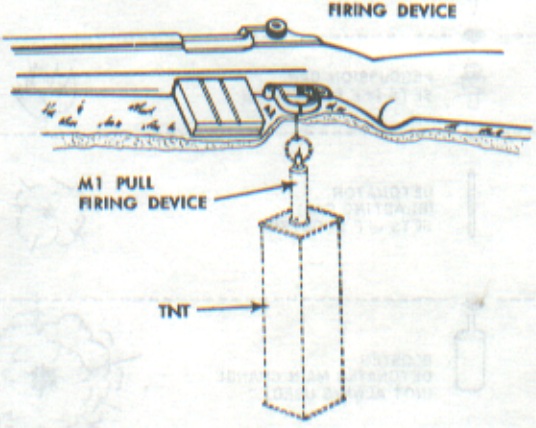
A. PRESSURE

WEIGHT OF FOOT STARTS EXPLOSIVE ACTION.



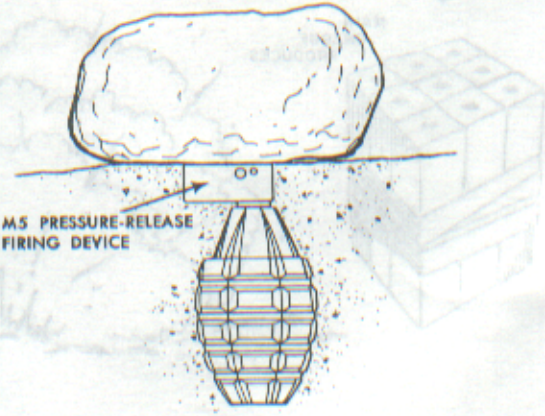
B. PULL

LIFTING THE SOUVENIR STARTS EXPLOSIVE ACTION.



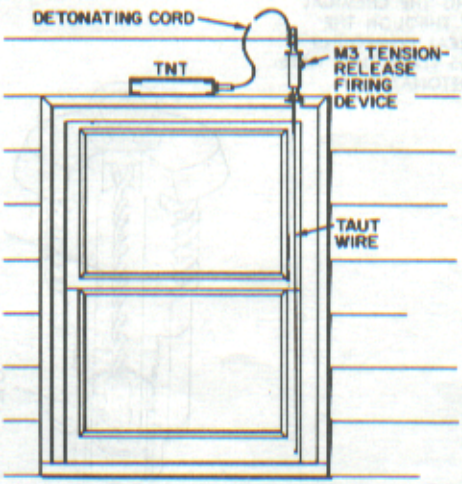
C. PRESSURE-RELEASE

MOVING THE STONE STARTS EXPLOSIVE ACTION.



D. TENSION-RELEASE

RAISING LOWER SASH STARTS EXPLOSIVE ACTION.

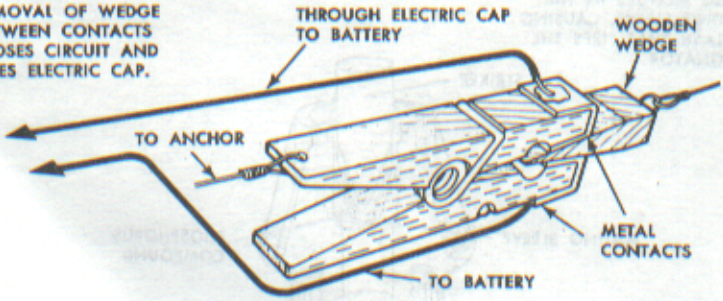


7. Firing Device Internal Actions

A FIRING DEVICE, WHEN ACTUATED MAY FUNCTION INTERNALLY IN MANY WAYS TO INITIATE THE FIRING CHAIN.

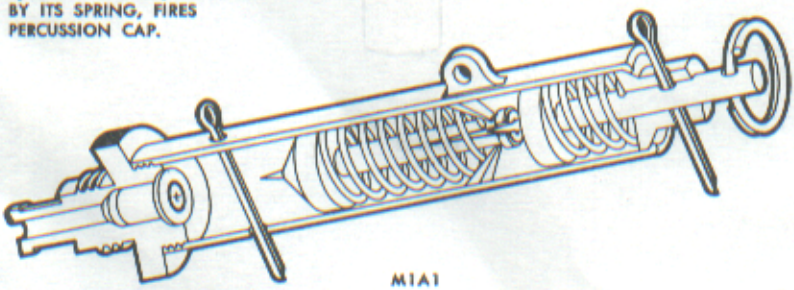
A. ELECTRIC

REMOVAL OF WEDGE BETWEEN CONTACTS CLOSES CIRCUIT AND FIRES ELECTRIC CAP.



B. MECHANICAL

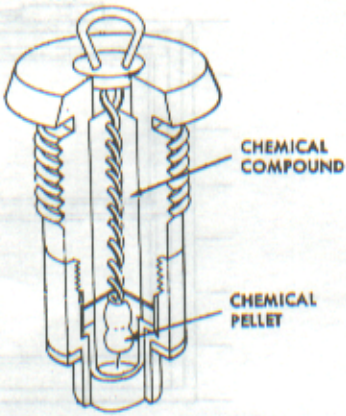
RELEASED STRIKER, DRIVEN BY ITS SPRING, FIRES PERCUSSION CAP.



M1A1

C. PULL-FRICTION

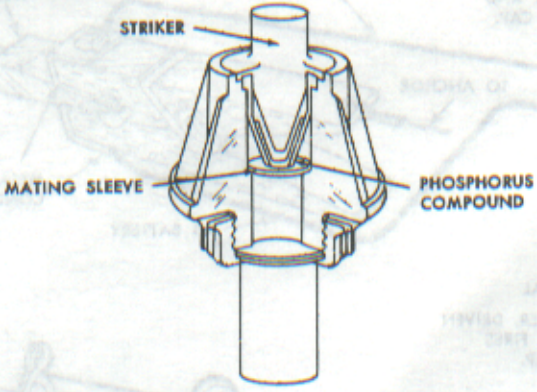
PULLING THE CHEMICAL PELLET THROUGH THE CHEMICAL COMPOUND CAUSES FLASH THAT FIRES THE DETONATOR.



PULL-FRICTION FUZE, WEST WW II GERMANY

D. PRESSURE-FRICTION

PRESSURE ON TOP OF THE STRIKER FORCES ITS CONE-SHAPED END INTO THE PHOSPHORUS AND GLASS MIXTURE IN THE MATING SLEEVE, CAUSING A FLASH THAT FIRES THE DETONATOR

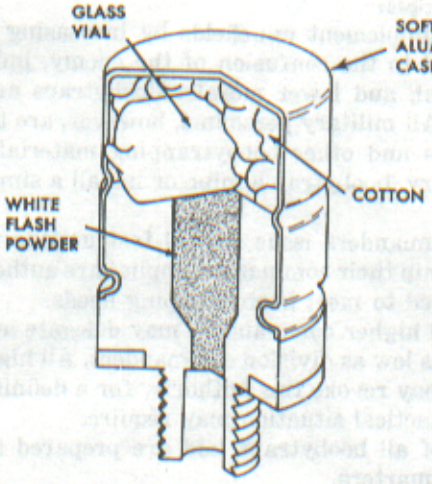


MODEL 1952 FRANCE

E. CHEMICAL

(1) PRESSURE

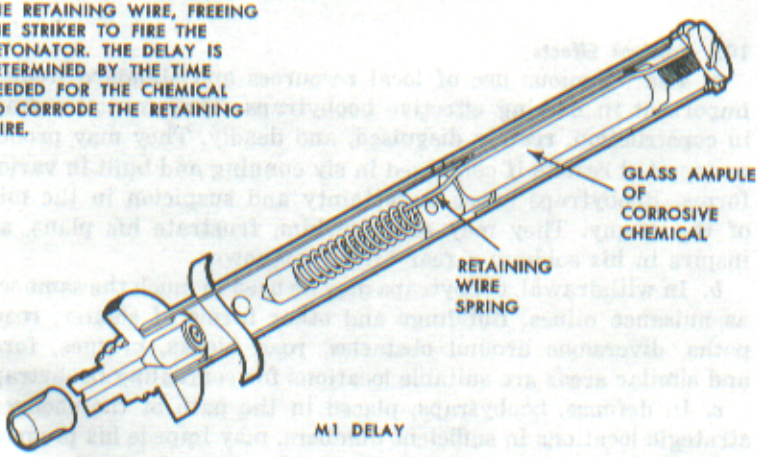
PRESSURE ON THE TOP BREAKS THE VIAL, FREEING THE SULPHURIC ACID TO MIX WITH THE FLASH POWDER, PRODUCING A FLAME THAT FIRES THE DETONATOR.



WW II GERMANY
BUCK CHEMICAL
FUZE

(2) DELAY

CRUSHING THE AMPULE RELEASES THE CHEMICAL TO CORRODE THE RETAINING WIRE, FREEING THE STRIKER TO FIRE THE DETONATOR. THE DELAY IS DETERMINED BY THE TIME NEEDED FOR THE CHEMICAL TO CORRODE THE RETAINING WIRE.



M1 DELAY

CHAPTER 2

USE OF BOOBYTRAPS

Section I. BASIC DOCTRINE

8. Tactical Principles

Boobytraps supplement minefields by increasing their obstacle value. They add to the confusion of the enemy, inflict casualties, destroy material, and lower morale. Boobytraps are usually laid by specialists. All military personnel, however, are trained in handling explosives and other boobytrapping material, so that they may, if necessary, boobytrap a mine or install a simple boobytrap.

9. Authority

a. Army commanders issue special instructions for the use of boobytraps within their command. Supplies are authorized and provided as required to meet boobytrapping needs.

b. Army and higher commanders may delegate authority to lay boobytraps to as low as division commanders. All higher commanders, however, may revoke this authority for a definite or indefinite period, as the tactical situation may require.

c. Records of all boobytraps laid are prepared and forwarded to higher headquarters.

d. Enemy boobytraped areas, as soon as discovered, are reported to higher headquarters to keep all interested troops advised of enemy activities. If possible, all boobytraps are neutralized; otherwise they are properly marked by warning signs.

Section II. PLANNING

10. Tactical Effects

a. The ingenious use of local resources and standard items is important in making effective boobytraps. They must be simple in construction, readily disguised, and deadly. They may produce unexpected results if conceived in sly cunning and built in various forms. Boobytraps cause uncertainty and suspicion in the mind of the enemy. They may surprise him, frustrate his plans, and inspire in his soldiers a fear of the unknown.

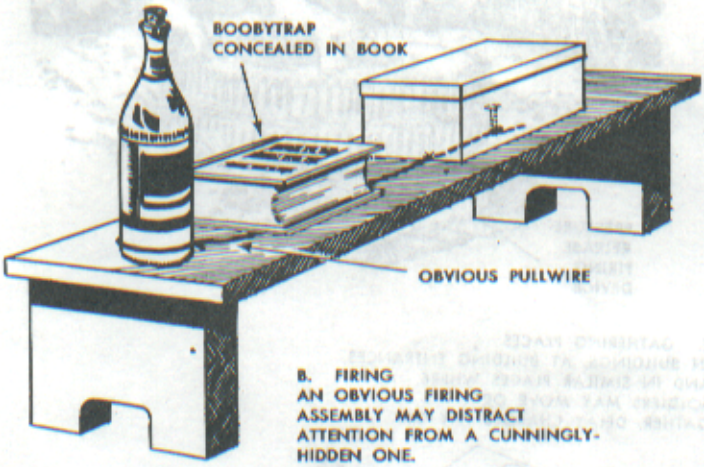
b. In withdrawal, boobytraps may be used in much the same way as nuisance mines. Buildings and other forms of shelter, roads, paths, diversions around obstacles, road blocks, bridges, fords, and similar areas are suitable locations for concealing boobytraps.

c. In defense, boobytraps, placed in the path of the enemy at strategic locations in sufficient numbers, may impede his progress, prevent detailed reconnoissance, and delay disarming and removal of minefields.

11. Basic Principles

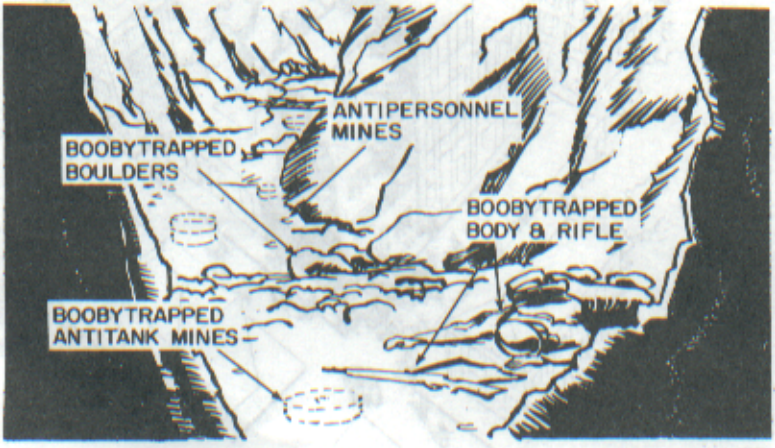
Certain basic principles, as old as warfare itself, must be followed to get the optimum benefit from boobytraps. Knowledge of these principles will aid the soldier, not only in placing boobytraps expertly, but in detecting and avoiding those of the enemy.

A. APPEARANCES
CONCEALMENT IS MANDATORY TO SUCCESS. ALL LITTER AND OTHER EVIDENCES OF BOOBYTRAPING MUST BE REMOVED.

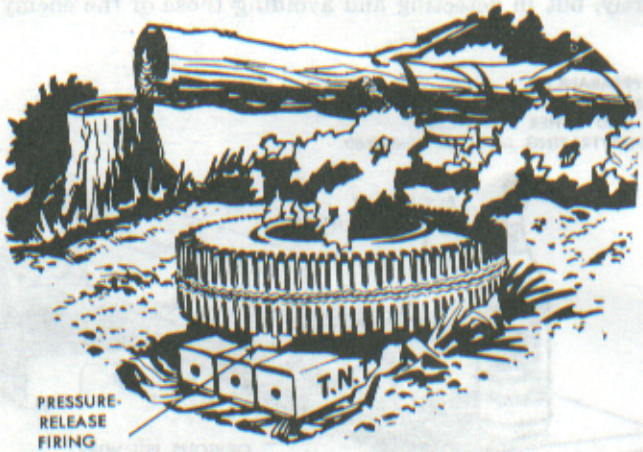


B. FIRING
AN OBVIOUS FIRING ASSEMBLY MAY DISTRACT ATTENTION FROM A CUNNINGLY-HIDDEN ONE.

C. LIKELY AREAS
DEFILES OR OTHER CONSTRICTED AREAS ARE EXCELLENT LOCATIONS.



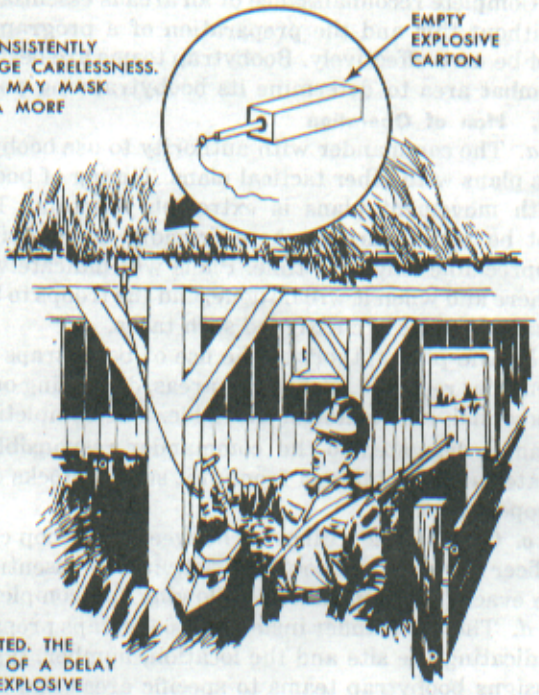
D. OBSTACLES
ROAD BLOCKS, FALLEN
TREES, LITTER, ETC.,
ARE IDEAL LOCATIONS



E. GATHERING PLACES
IN BUILDINGS, AT BUILDING ENTRANCES,
AND IN SIMILAR PLACES WHERE
SOLDIERS MAY MOVE OR
GATHER, DELAY CHARGES PAY OFF.

F. APPEAL TO CURIOSITY
BOOBYTRAPS LAID IN
BOLD POSITIONS TO DARE
THE CURIOUS GET RESULTS.

G. BLUFF
DUMMY BOOBYTRAPS, CONSISTENTLY
REPEATED, MAY ENCOURAGE CARELESSNESS.
AN OBVIOUS BOOBYTRAP MAY MASK
ANOTHER AND PERHAPS A MORE
DEADLY ONE.



H. LURES
BOOBYTRAPS MAY BE BAITED. THE
UNEXPECTED DETONATION OF A DELAY
ACTION INCENDIARY OR EXPLOSIVE
BOOBYTRAP MAY SCATTER TROOPS OR
DETOUR THEM INTO A MORE HEAVILY LAID
AREA.

12. Location of Charges

a. Preparation. Small compact boobytraps are the most desireable for use in raids in enemy-held territory. Each member of a team must carry his own supplies and be able to operate independently. Boobytraps should be assembled, except for the attachment of the firing device, before entering enemy territory. This will reduce the work at the site to the minimum.

b. Location. Charges should be placed where they will do the most damage. A charge detonated against a stone wall will expend its force in magnified intensity away from the wall. The force of an explosion on the ground will affect the surrounding air more if the charge is placed on a hard surface. This deflects the explosive wave upward. A charge detonating 6 to 10 feet above the ground will damage a larger area than one laid on or below the surface.

c. Characteristics. Many inexpensive boobytraps, simple to make and easy to lay, will delay and confuse the enemy more than a small number of the expensive and complex kind. Complex mechanisms

cost more, require more care in laying, and offer little more advantage than the simple type.

13. Reconnaissance

Complete reconnaissance of an area is essential to good planning. Without this and the preparation of a program, boobytraps may not be used effectively. Boobytrap teams are best suited to survey a combat area to determine its boobytrapping possibilities.

14. Plan of Operation

a. The commander with authority to use boobytraps coordinates his plans with other tactical plans. Timing of boobytrap operations with movement plans is extremely essential. Boobytraps should not be laid in areas where friendly troops will remain for any appreciable length of time. Plans will indicate what is to be done, where and when it will be done, and the troops to be used. Generally, trained troops are assigned such tasks.

b. The plan authorizes the use of boobytraps and the types and densities required in specified areas, depending on the terrain, time, personnel, and material available. The completion of the detailed plan is delegated to the commander responsible for installation. Materials are obtained from unit supply stocks on the basis of the proposed action.

c. Complete coordination between the troop commander and the officer supervising boobytrap activities is essential. The area should be evacuated immediately following the completion of the job.

d. The commander installing boobytraps prepares a detailed plan indicating the site and the location, number, type, and setting. He assigns boobytrap teams to specific areas and the laying of specified types. The plan covers arrangements for supplies and transportation and designates the location where all preliminary work on boobytraps will be done. Time tables are established to insure completion of the work to comply with withdrawal phases of tactical plans.

e. In hasty withdrawal, when there is no time for planning, each team will be given a supply of material with instructions for making the best possible use of it in the time allowed.

f. Boobytrap planning must give proper consideration to all known characteristics of the enemy. Members of teams should study the personal habits of enemy soldiers, constantly devising new methods to surprise them. Repetitions may soon become a pattern easily detected by an alert enemy.

g. Withdrawal operations are the most desirable of all for laying boobytraps. When an enemy meets a boobytrap at the first obstacle, his progress throughout the area will be delayed even though no others have been laid. A few deadly boobytraps and many dummies, laid indiscriminately, can inspire great caution. Dummies, however, should be unserviceable or useless items. Never throw away material that may return to plague friendly forces!

Section III. INSTALLATION

15. Responsibilities

a. A commander authorized to use boobytraps is responsible for all within his zone of command. He will keep adequate records showing their type, number, and location, and prepare information on those laid and on practices followed by the enemy.

b. Management of boobytrap services may be delegated to the engineer staff officer.

c. Unit commanders must know the location of all boobytraps in their areas and keep all subordinates so advised. Subordinates are also responsible for reporting to higher headquarters all new information obtained on enemy boobytraps.

d. Officers responsible for laying boobytraps prepare plans, supervise preliminary preparations, and direct their installation. They forward to proper authority a detailed report of their progress, advise all concerned when changes are made, and report to engineer intelligence units the discovery of any new enemy devices or low-cunning practices.

e. Engineer and infantry units, with special training, have the responsibility of installing and neutralizing boobytraps. Since adequate numbers of trainees may not always be available, all troops are given familiarity instruction in boobytrapping.

16. Procedures

Like all activities involving explosives, boobytrapping is dangerous only because of mistakes men make. Prescribed methods must be followed explicitly in the interest of personal safety and overall effectiveness.

a. Before assemblying a boobytrap, all components should be inspected for serviceability. They must be complete and in working order. All safeties and triggering devices must be checked to insure proper action, and for rust or dents that might interfere with mechanical action.

b. If a boobytrapping plan is not available, one must be prepared on arrival at the site, so that the material obtained will be required items only. A central control point should be established in each boobytrap area where supplies may be unloaded and from which directions may be given. In areas where many boobytraps are concentrated, safe passage routes from the control point to each location must be marked clearly. Lines or tape may be useful where vegetation is heavy. The control man is the key man.

c. Several teams may operate from one control point. Each team (rarely more than two men) is assigned to a specific area and supplies are issued only as needed. Each detail commander must make certain that every man knows his job and is competent to do it. Teams will remain separated so that one may not suffer from the mistake of another. When a job is completed, all teams

must report to control man before going elsewhere.

d. One person in each team is designated leader to direct all work. If possible, members of a team will avoid working close together when a boobytrap is assembled. One member should do all technical work and the other be a helper to carry supplies, provide assistance needed, and learn the skills needed.

e. Boobytraps laid during raids into enemy held territory should be small, simple, and easily installed. Each member of a party must carry the supplies he needs. The use of boobytraps under these conditions, when accurate records are impossible, may be a hazard to friendly troops if raids into the same area should become necessary.

f. Procedure for installing boobytraps is as follows:

(1) Select the site that will produce the optimum effect when the boobytrap is actuated.

(2) Lay the charge, then protect and conceal it.

(3) Anchor the boobytrap securely, with nails, wire, rope, or wedges, if necessary.

(4) Camouflage or conceal, if necessary.

(5) Teams arm boobytraps systematically, working toward a safe area.

(6) Leave the boobytrapped area clean. Carry away all items that might betray the work that has been done, such as loose dirt, empty boxes, tape, and broken vegetation. Obliterate footprints.

17. Reporting, Recording, and Marking

Boobytraps are reported and recorded for the information of tactical commanders and the protection of friendly troops from casualty. Boobytrap installations are reported and recorded as nuisance minefields, whether the area contains both boobytraps and mines or boobytraps alone.

a. Reports

(1) *Intent.* This is transmitted by the fastest means available consistent with signal security. It includes the location of the boobytrapped area selected, the number and type of mines to be laid (if antitank mines are boobytrapped), boobytraps to be laid, the estimated starting and completing time, and the tactical purpose. The report is initiated by the commander authorized to lay the field and forwarded to higher headquarters.

(2) *Initiation of Laying.* This report is transmitted by the fastest means available consistent with signal security. It contains the location and extent of the field, total number of mines and boobytraps to be laid, and estimated time of completion. The commander of the unit installing

COMBAT BN | JOHN R. TAYLOR 1ST LT. 07F183 | 1800 | 30 JUNE 53 | 1B-A-9R

SEXTON

3570 I | 1" = 50 PACES

Robert W. Whittle Jnr.

RECORD OF BOOBYTRAPS PLACED

SCHOOL "A" 3 TRAPS PLACED

1. Pressure - release device and TNT placed under front door sill. Operated by opening door.

2. Pressure device and TNT placed under ground sheet of staircase from ground to first floor. Operated by pressure

3. TNT under center of lobby floor. Connected to light current. Operated by throwing on switch at entrance.

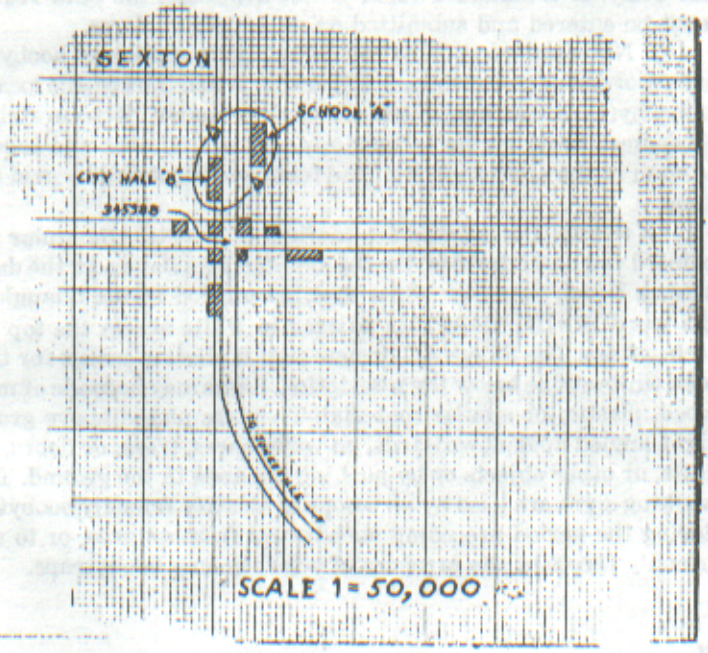
CITY HALL "B" 2 TRAPS PLACED

1. Pressure - release device and TNT in grass Embankment in basement. Operated by lifting lid of Embankment.

2. Pressure device and TNT under loose floorboard just inside main entrance door. Operated by pressure on floorboard.

ALL TEMPORARY MARKERS REMOVED AT 301800

John R. Taylor 1st Lt.



the field sends the report to the commander that directed him to lay it.

(3) *Completion.* The report of completion is transmitted by the fastest possible means. It contains the number and type of boobytraps laid, location and extent of the field or area and the time of completion. The report is forwarded to army level. When boobytraps are laid, either alone or with mines, the report of intent and the report of initiation of laying will include the estimated number of boobytraps to be placed and the report of completion, the number placed.

b. Records. Boobytraps are recorded as nuisance mine fields on the standard mine field record form. It is filled in as follows:

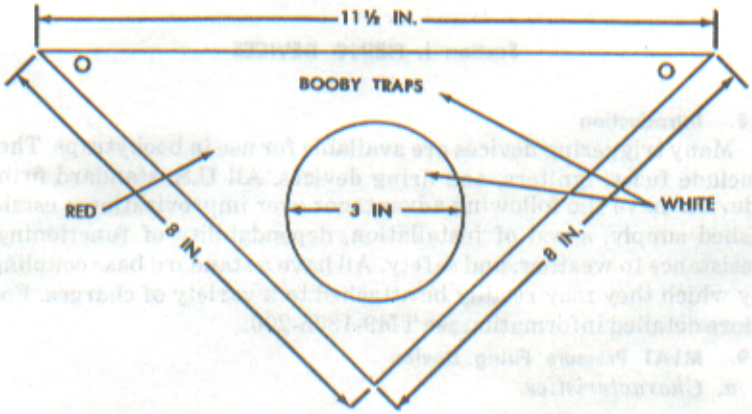
(1) The general locations are shown on the sketch, using the appropriate symbol. Boobytrapped areas or buildings are lettered serially, "A" being the nearest to the enemy.

(2) The number, types, locations, and methods of operation of boobytraps are entered in the NOTES section of the form. If space is lacking, additional sheets may be attached. If the boobytrap cannot be adequately described in a few short sentences, a sketch of minimum details will be included.

(3) The record is prepared simultaneously with the laying of the boobytrap and forwarded through channels to army level without delay. If a standard form is not available, the data required must be entered and submitted on an expedient form.

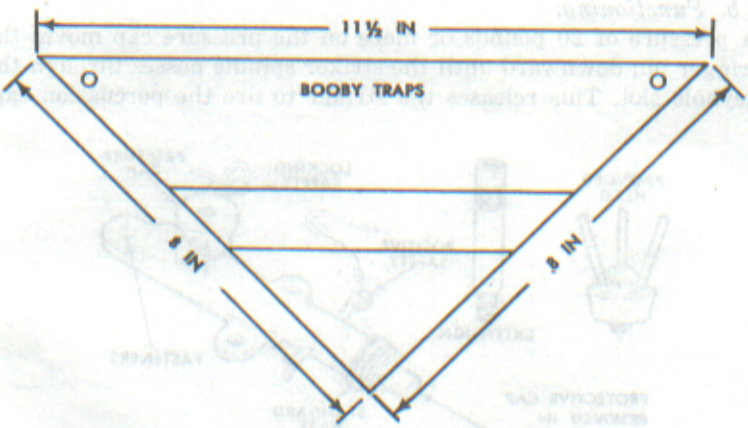
(4) Nuisance mine fields containing both mines and boobytraps are recorded as prescribed in FM 20-32. When the specific locations of boobytraps and manufactured devices cannot be accurately recorded (scattered laying in open areas) their number and type are entered in the notes section of the form and identified by grid coordinates.

c. Marking. Boobytraps are marked by special triangular signs painted red on both sides. On the side facing away from the danger area, a 3-inch diameter white disc, is centered in the triangle and the word BOOBYTRAPS is painted in white across the top in 1-inch letters. The STANAG or new sign is similar except for the 1-inch white stripe below the inscription. Signs may be made of metal, wood, plastic, or similar material. They are placed above ground, right-angled apex downwards, on wire fences, trees, or doors, windows, or other objects or by pushing the apex in the ground. These working signs are used by all troops to identify friendly boobytraps during the period preceding withdrawal from an area, or to warn friendly forces of the presence of active enemy boobytraps.



d. Abandonment. When abandoning a boobytrapped area to the enemy, all markers, wire, etc., are removed.

e. Signs. Signs are also used to mark enemy boobytraps or boobytrapped areas.



CHAPTER 3

BOOBYTRAPPING EQUIPMENT

Section I. FIRING DEVICES

18. Introduction

Many triggering devices are available for use in boobytraps. They include fuzes, igniters, and firing devices. All U.S. standard firing devices have the following advantages over improvisations; established supply, speed of installation, dependability of functioning, resistance to weather, and safety. All have a standard base coupling by which they may readily be attached to a variety of charges. For more detailed information see TM9-1375-200.

19. M1A1 Pressure Firing Device

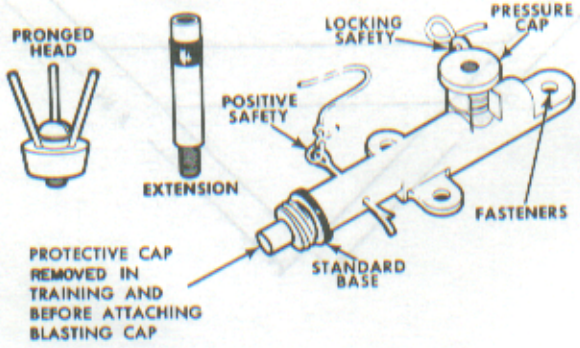
a. Characteristics.

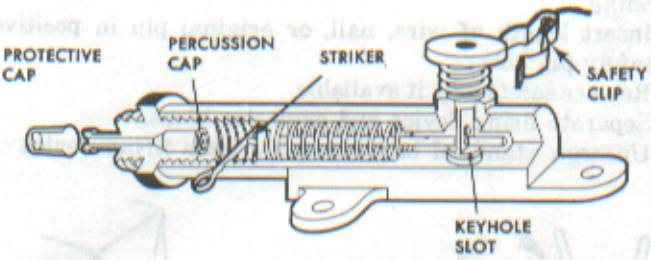
		Dimensions			
Case	Color	D	L	Internal Action	Initiating Action
Metal	OD	⅝ in	2¾ in	Spring-driven striker with keyhole slot release	20 lb pressure or more

Safeties	Accessories	Packaging
Safety clip and positive safety pin	3-pronged pressure head and extension rod	Five units with standard bases packed in cardboard carton. Thirty cartons shipped in wooden box.

b. Functioning.

A pressure of 20 pounds or more on the pressure cap moves the trigger pin downward until the striker spindle passes through the keyhole slot. This releases the striker to fire the percussion cap.





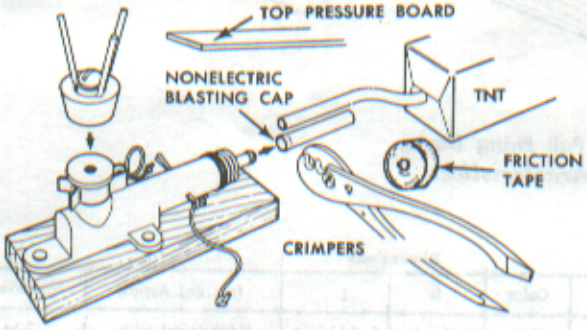
c. Installing.

(1) Remove protective cap from base and crimp on a nonelectric blasting cap. *Crimper jaws should be placed no farther than ¼ inch from open end of blasting cap.*

(2) Assemble 3-pronged pressure head and extension rod and screw in top of pressure cap, if needed.

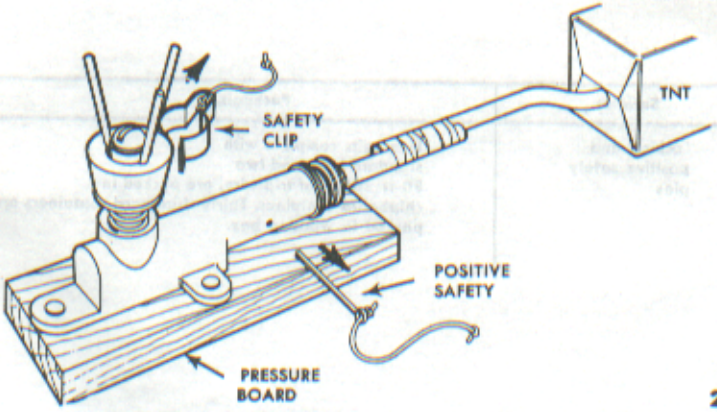
(3) Attach firing device assembly to standard base.

(4) Attach firing device assembly to charge.



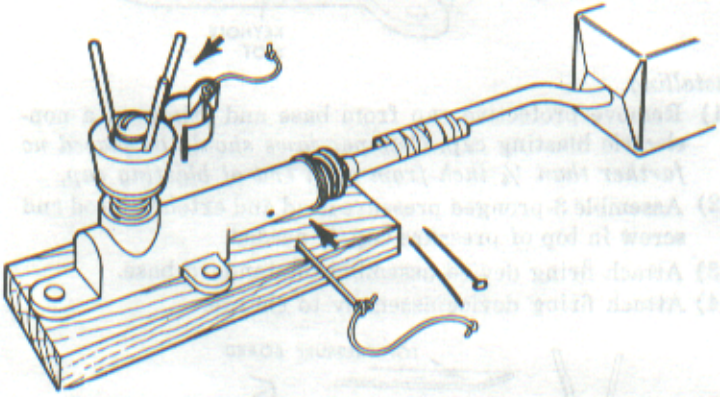
NOTE. If top pressure board is used, allow clearance space between it and top of prongs or pressure cap.

d. Arming. Remove safety clip first and *positive pin last.*



e. Disarming.

(1) Insert length of wire, nail, or original pin in positive safety pin hole.
(2) Replace safety clip, if available.
(3) Separate firing device and explosive block.
(3) Unscrew standard base assembly from firing device.



20. M1 Pull Firing Device

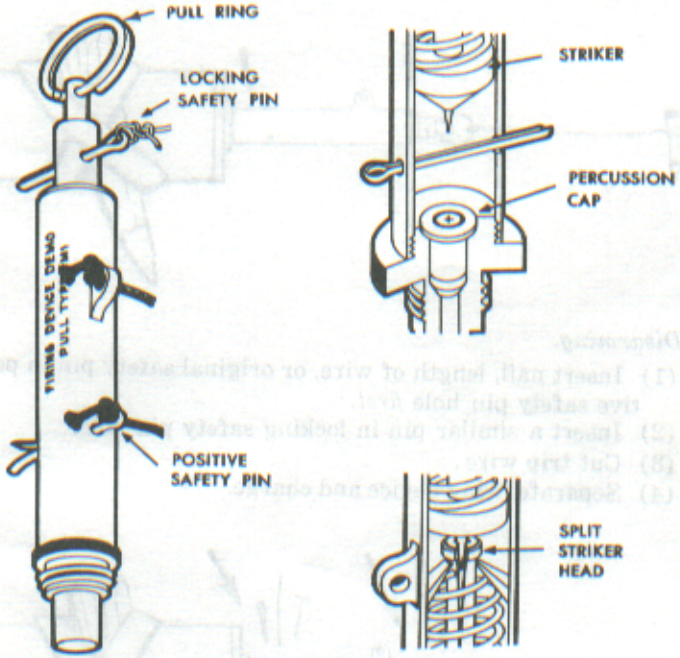
a. Characteristics.

Case	Color	Dimensions D	Dimensions L	Internal Action	Initiating Action
Metal	OD	9/16 in	3 5/16 in	Mechanical with split-head striker release	3 to 5 lb pull on trip wire

Safeties	Packaging
Locking and positive safety pins	Five units complete with standard base and two 80-ft spools of trip wire, are packed in chipboard container. Thirty chipboard containers are packed in wooden box.

b. Functioning.

A pull of 3 to 5 lb. on trip wire withdraws tapered end of release pin from split head of striker. This frees striker to fire the percussion cap.

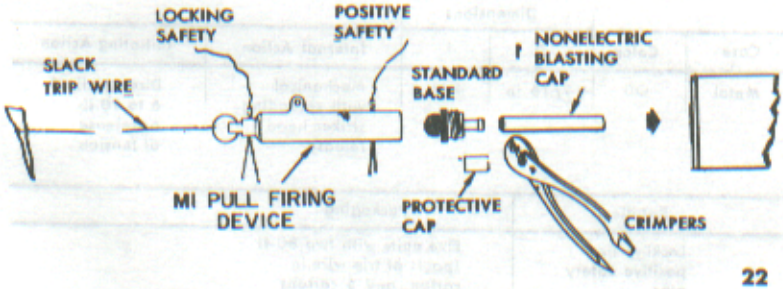


c. Installing.

(1) Remove protective cap.

(2) With crimpers, attach blasting cap to standard base. *Crimper jaws should be placed no farther than ¼ in. from open end of blasting cap.*

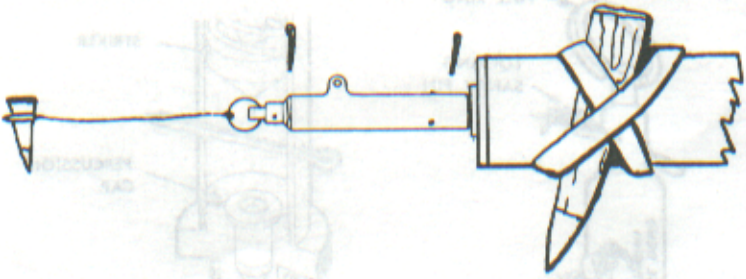
(3) Attach firing device assembly to charge.



d. Arming.

(1) Anchor trip wire and fasten other end to pull ring.

(2) Remove locking safety pin first and *positive safety pin last.*



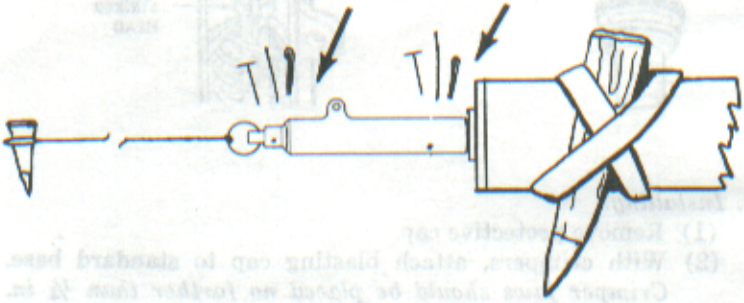
e. Disarming.

(1) Insert nail, length of wire, or original safety pin in positive safety pin hole *first.*

(2) Insert a similar pin in locking safety pin hole.

(3) Cut trip wire.

(4) Separate firing device and charge.



21. M3 Pull-Release Firing Device

a. Characteristics.

Case	Color	Dimensions D	Dimensions L	Internal Action	Initiating Action
Metal	OD	9/16 in	4 in	Mechanical with spreading striker head release	Direct pull of 6 to 10 lb or release of tension

Safeties	Packaging
Locking and positive safety pins	Five units with two 80-ft spools of trip wire in carton, and 5 cartons packed in wooden box

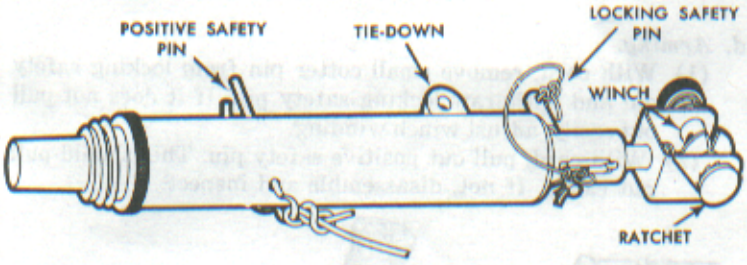
b. Functioning.

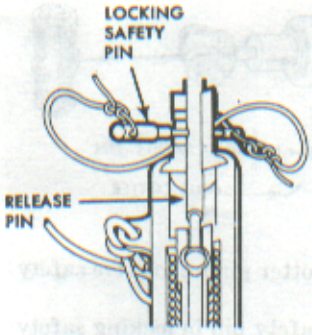
(1) Pull.

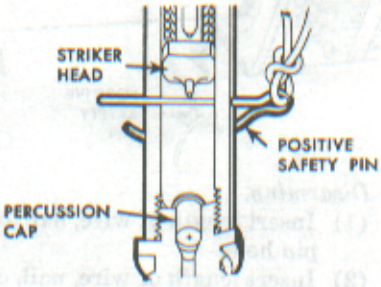
A pull of 6 to 10 lb. on taut trip wire raises release pin until shoulder passes constriction in barrel. The striker jaws then spring open, releasing striker to fire percussion cap.

(2) Tension-release.

Release of tension (cutting of taut trip wire) permits spring-driven striker to move forward, separate from release and fire percussion cap.







c. Installing.

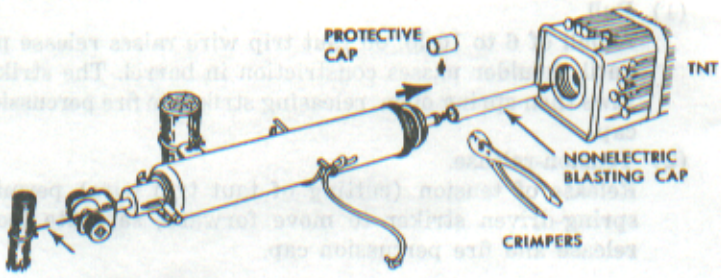
(1) Remove protective cap.

(2) With crimpers, attach blasting cap to standard base. *Crimper jaws should be placed no farther than ¼ in. from open end of blasting cap.*

(3) Attach firing device assembly to anchored charge (must be firm enough to withstand pull of at least 20 lb.).

(4) Secure one end of trip wire to anchor and place other end in hole in winch.

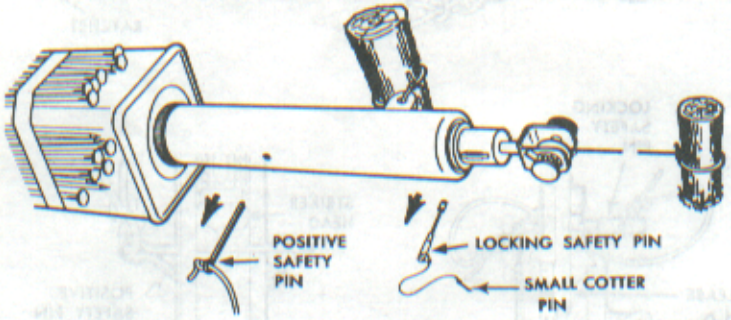
(5) With knurled knob draw up trip wire until locking safety pin is pulled into wide portion of safety pin hole.



d. Arming.

(1) With cord, remove small cotter pin from locking safety pin and withdraw locking safety pin. If it does not pull out easily, adjust winch winding.

(2) With cord, pull out positive safety pin. This should pull out easily. If not, disassemble and inspect.



e. Disarming.

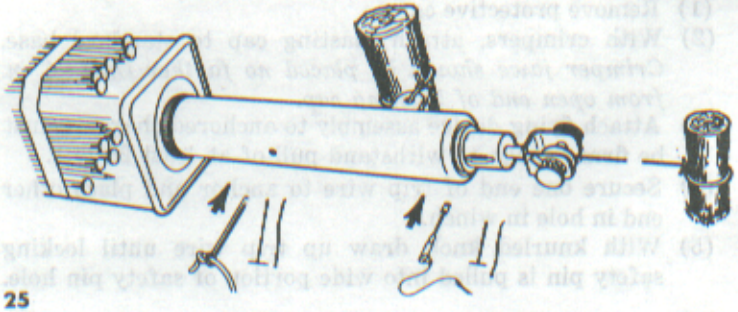
(1) Insert length of wire, nail, or cotter pin in positive safety pin hole.

(2) Insert length of wire, nail, of safety pin in locking safety pin hole.

(3) Check both ends and cut trip wire.

(4) Separate firing device from charge.

Note. Insert positive safety pin first. Cut trip wire last.



22. M5 Pressure-Release Firing Device

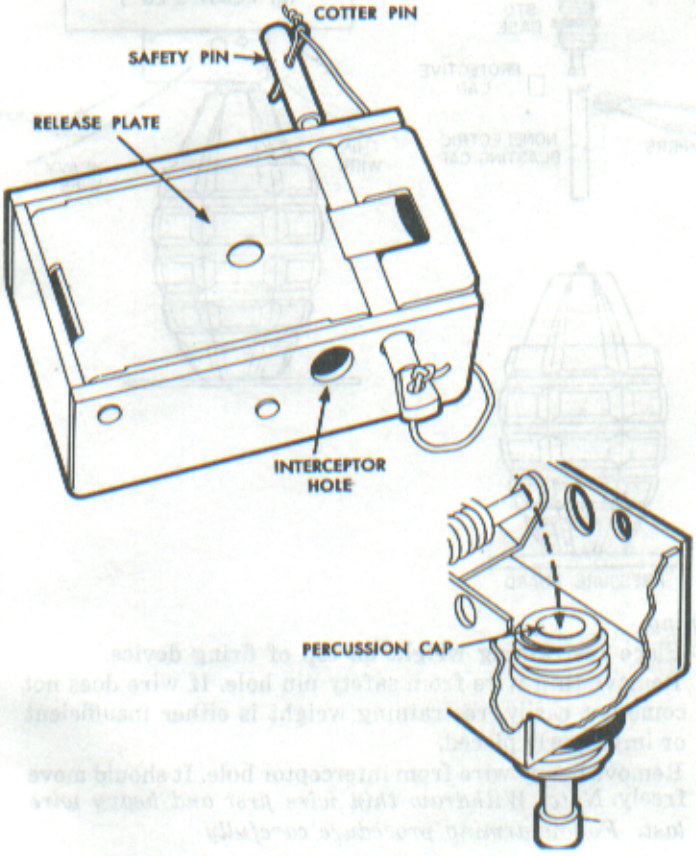
a. Characteristics.

Case	Color	Dimensions L	Dimensions W	Dimensions H,T	Internal Action	Initiating Action
Metal	OD	1 ¾	15/16	11/16	Mechanical with hinged plate release	removal of restraining wt, 5 lb or more

Accessories	Safeties	Packaging
Pressure board	Safety pin and hole for Interceptor pin	Four firing devices complete and four plywood pressure boards in paper carton. Five cartons are packaged in fiber board box and 10 of these shipped in wooden box.

b. Functioning.

Lifting or removing retaining weight releases striker to fire the percussion cap.



c. Installing.

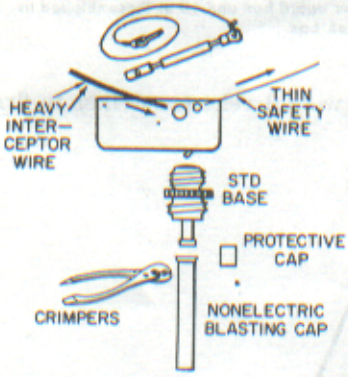
(1) Insert a length of 10-gage wire in interceptor hole. Bend slightly to prevent dropping out.

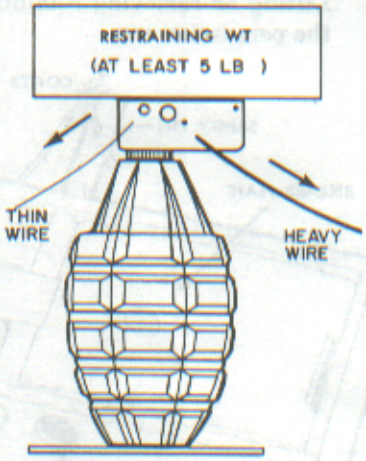
(2) Remove small cotter pin from safety pin.

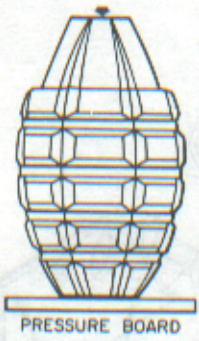
(3) Holding release plate down, replace safety pin with length of No. 18 wire. Bend wire slightly to prevent dropping out.

(4) Remove protective cap from base and with crimpers, attach blasting cap. *Crimper jaws should be placed no farther than ¼ inch from open end of blasting cap.*

(5) Secure firing device assembly in charge.







d. Arming.

(1) Place restraining weight on top of firing device.

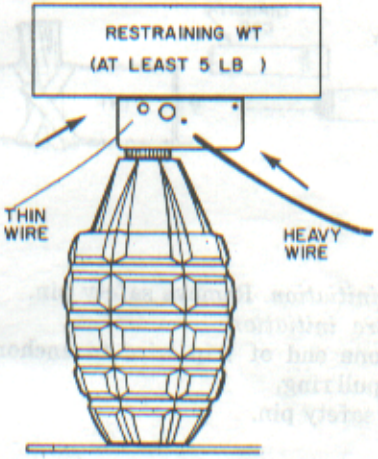
(2) Remove thin wire from safety pin hole. If wire does not come out easily, restraining weight is either insufficient or improperly placed.

(3) Remove heavy wire from interceptor hole. It should move freely. *Note. Withdraw thin wire first and heavy wire last. Follow arming procedure carefully*

e. Disarming.

(1) Insert length of heavy gage wire in interceptor hole. Bend wire to prevent dropping out. *Proceed carefully, as the slightest disturbance of the restraining weight might initiate the firing device.*

(2) Separate firing device from charge.



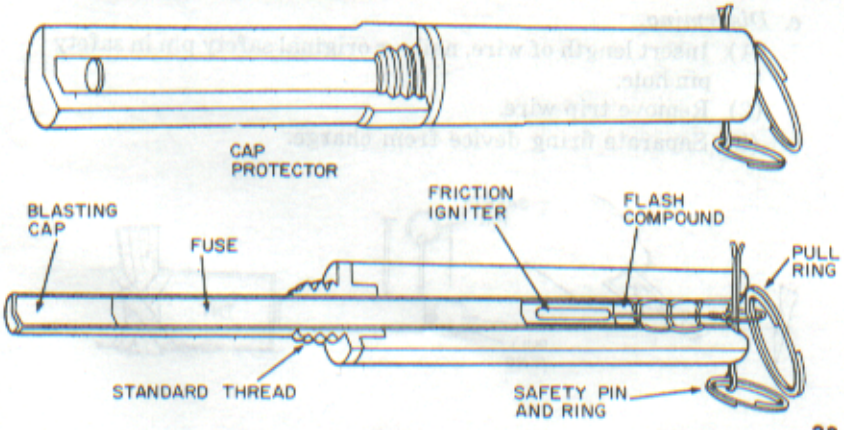
23. 15-Second Delay Detonator

a. Characteristics.

This device consists of a pull-friction fuse igniter, 15-second length of fuse, and blasting cap. The blasting cap is protected by a transit cap screwed on the base.

b. Functioning.

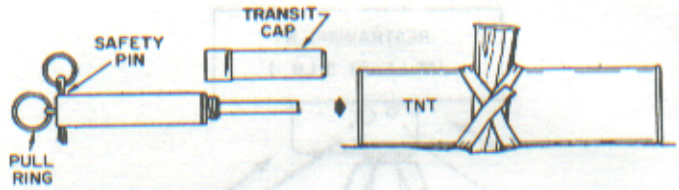
A strong pull on the pull ring draws the friction igniter through the flash compound, causing a flame which ignites the time fuse.



c. Installing.

(1) Unscrew transit cap from base.

(2) Secure device in charge.



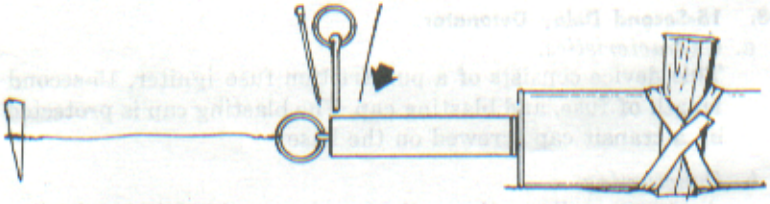
d. Arming.

(1) *Manual initiation.* Remove safety pin.

(2) *Trip wire initiation.*

(a) Attach one end of trip wire to anchor stake and the other to pull ring.

(b) Remove safety pin.

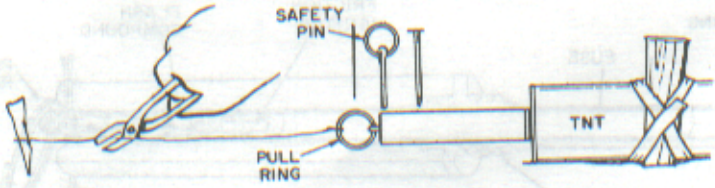


e. Disarming.

(1) Insert length of wire, nail, or original safety pin in safety pin hole.

(2) Remove trip wire.

(3) Separate firing device from charge.



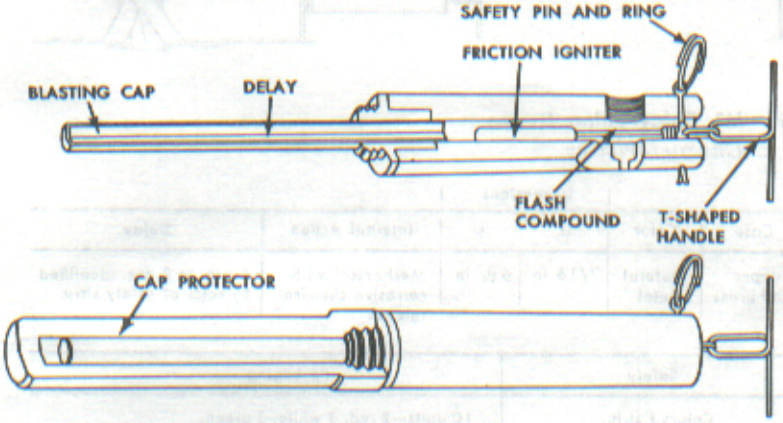
24. 8-Second Delay Detonator

a. Characteristics.

This device consists of a pull-type fuse lighter, 8-second length of fuse, and a blasting cap. The blasting cap is protected by a transit cap, screwed on the base.

b. Functioning.

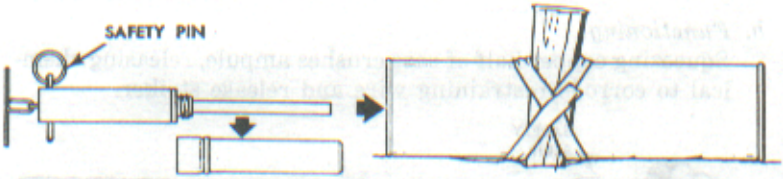
A strong pull on the T-shaped handle draws the friction igniter through the flash compound, causing a flame that ignites the time fuse.



c. Installing.

(1) Unscrew transit cap from base.

(2) Secure device in charge.



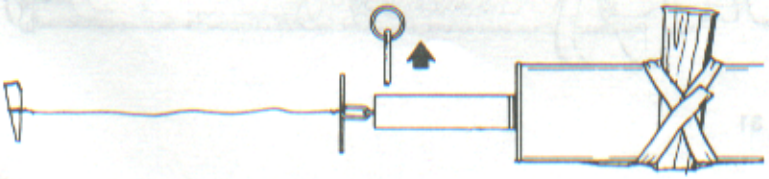
d. Arming.

(1) Manual initiation: Remove safety pin.

(2) Trip wire initiation.

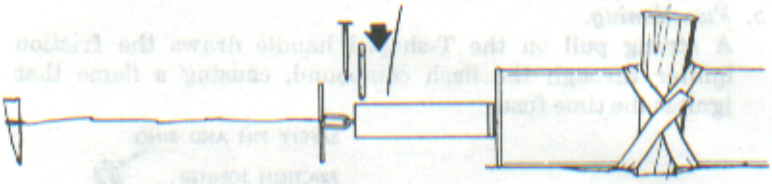
(a) Attach one end of trip wire to anchor stake and the other to pull ring.

(b) Remove safety pin.



e. Disarming.

(1) Insert length of wire, nail, or safety pin in safety pin hole.
(2) Remove trip wire.
(3) Separate firing device from charge.



25. M1 Delay Firing Device

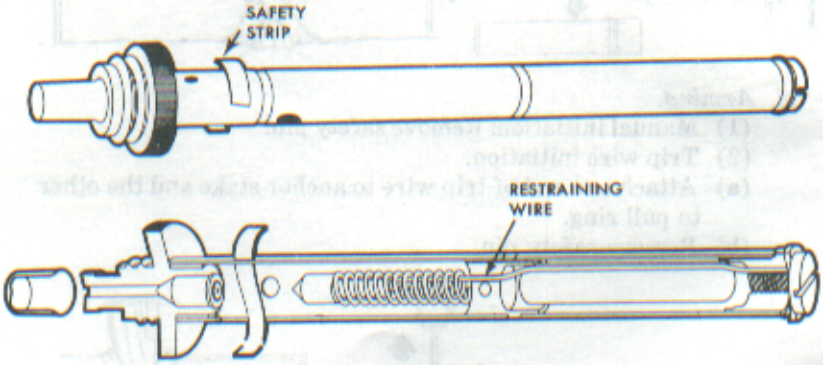
a. Characteristics.

Case	Color	Dimensions D	Dimensions L	Internal Action	Delay
Copper and brass	Natural Metal	7/16 in	6¼ in	Mechanical with corrosive chemical release	4 min to 9 dos, identified by color of safety strip

Safety	Packaging
Colored strip inserted in hole above percussion cap.	10 units—2 red, 3 white, 3 green, 1 yellow, and 1 blue—and a time delay temperature chart packed in paper board carton, 10 cartons in fiber board box, and 5 boxes in wooden box.

b. Functioning.

Squeezing copper half of case crushes ampule, releasing chemical to corrode restraining wire and release striker.



c. *Installing.*

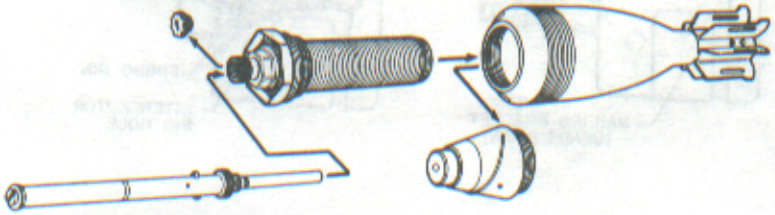
(1) Select device of proper delay.

(2) Insert nail in inspection hole to make sure that firing pin has not been released.

(3) Remove protective cap from base.

(4) With crimpers, attach blasting cap to base. *Crimper jaws should be placed no farther than ¼ in. from open end of blasting cap.*

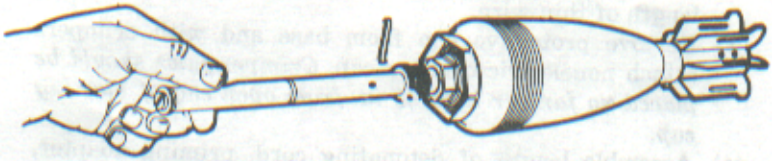
(5) Secure firing device assembly in destructor and then in charge.



d. *Arming.*

(1) Crush ampule by squeezing the copper portion of case.

(2) Remove safety strip.



e. *Disarming.*

There is no safe way of disarming this firing device. If disarming is necessary, insert an improvised safety pin through inspection holes.

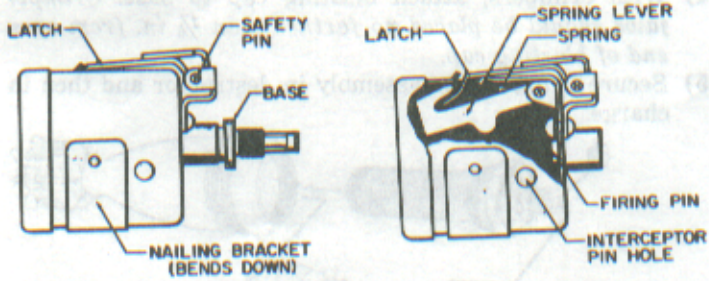
26. M1 Pressure-Release Firing Device

a. *Characteristics.*

		Dimensions				
Case	Color	L	W	Ht	Internal Action	Restraining Pressure
Metal	OD	3 in	2 in	2 in	Mechanical with springed latch release	3 lb or more

Safeties	Issue
Safety pin and hole for interceptor pin	Obsolete, but many are still available

b. Functioning.
Lifting or removing restraining weight unlatches lever, releasing striker to fire percussion cap.



c. Installing.

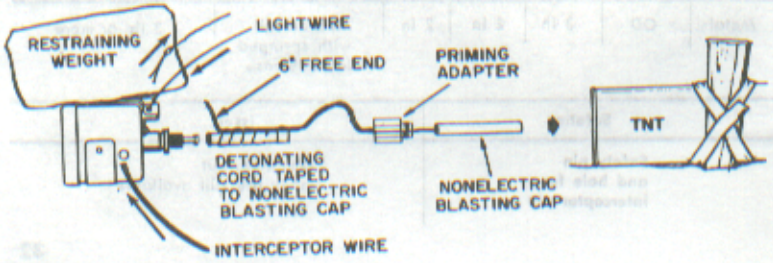
(1) Insert a length of heavy gage wire in interceptor hole. Bend slightly to prevent dropping out.

(2) Holding down latch, remove safety pin and replace with length of thin wire.

(3) Remove protective cap from base and with crimpers attach nonelectric blasting cap. *Crimper jaws should be placed no farther than ¼ in. from open end of blasting cap.*

(4) Assemble length of detonating cord, priming adapter, nonelectric blasting cap, and explosive block.

(5) Attach free end of detonating cord to blasting cap on M1 release device with friction tape, allowing 6 in. of detonating cord to extend beyond joint.



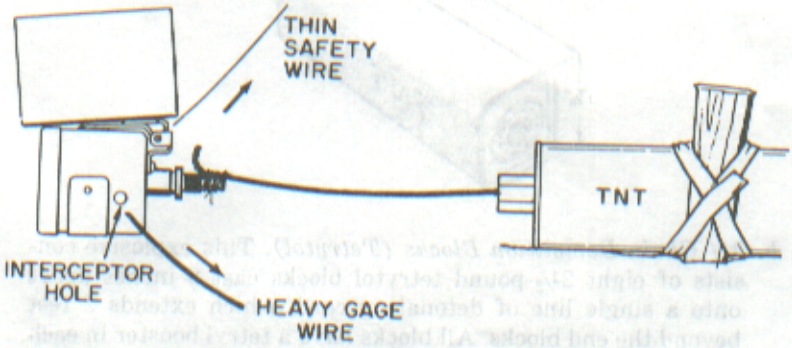
d. Arming.

(1) Place restraining weight on top of firing device.

(2) Remove thin wire from safety pin hole. If it does not come out easily, restraining weight is either insufficient or improperly placed.

(3) Remove heavy wire from interceptor hole.

Note. Proceed carefully.

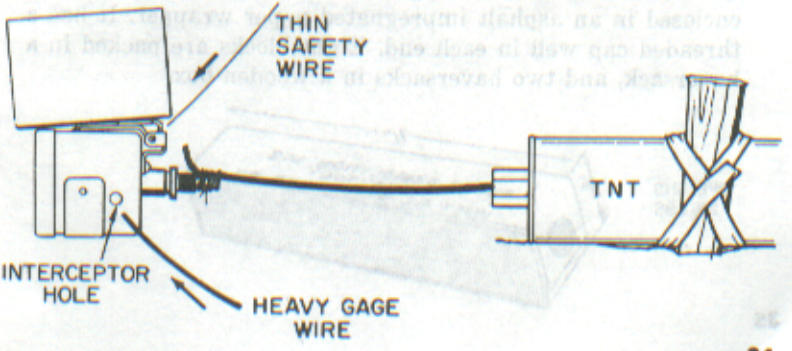


e. Disarming.

(1) *Proceed carefully as the slightest disturbance of restraining weight might unlatch lever and detonate the mine.* Insert length of heavy gage wire in interceptor hole. Bend wire to prevent dropping out.

(2) Insert length of thin wire in safety pin hole, if possibile.

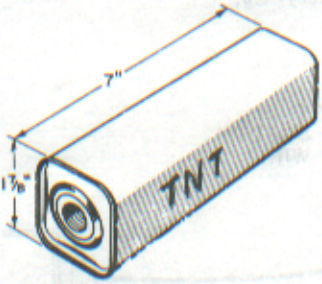
(3) Separate firing device assembly and explosive charge.



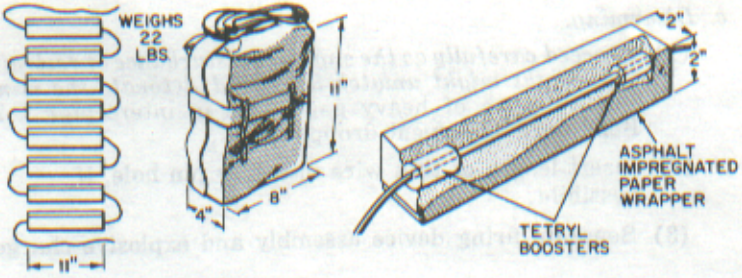
Section II. DEMOLITION MATERIALS

27. Explosives and Accessories (For more detailed information, see FM5-25 and TM 9-1375-200.)

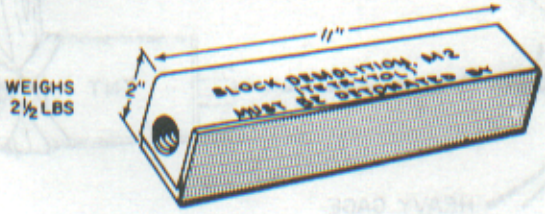
a. TNT. This is issued in ¼, ½ and 1-pound blocks in a cardboard container with lacquered metal ends. One end has a threaded cap well. Half-pound blocks are obtained by cutting a 1-pound package in the center.



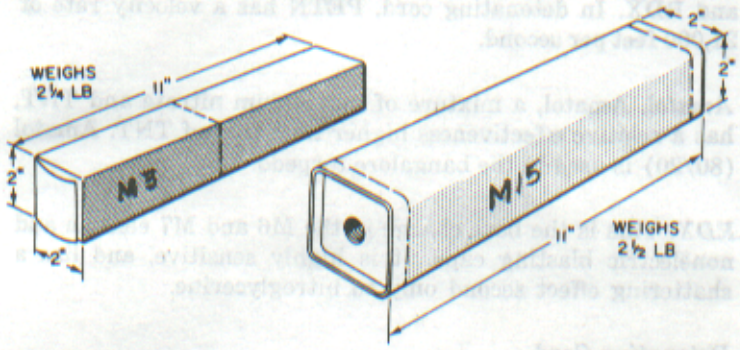
b. M1 Chain Demolition Blocks (Tetrytol). This explosive consists of eight 2½-pound tetrytol blocks cast 8 inches apart onto a single line of detonating cord, which extends 2 feet beyond the end blocks. All blocks have a tetryl booster in each end. Each chain is packed in a haversack, and two haversacks in a wooden box.



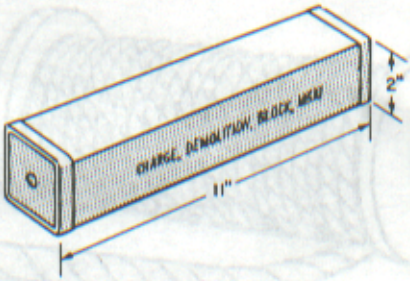
c. M2 Demolition Block (Tetrytol). The M2 demolition block is enclosed in an asphalt impregnated paper wrapper. It has a threaded cap well in each end. Eight blocks are packed in a haversack, and two haversacks in a wooden box.



d. M3 and M5 Demolition Blocks (Composition C3). These consist of a yellow, odorous, plastic explosive more powerful than TNT. The M3 block has a cardboard wrapper perforated around the middle for easy opening. The M5 block has a plastic container with a threaded cap well. Eight M3 or M5 blocks are packed in a haversack; and two haversacks, in a wooden box.



e. M5A1 Demolition Block (Composition C4). This is a white plastic explosive more powerful than TNT, but without the odor of C3. Each block is wrapped in plastic covering with a threaded cap well in each end. Twenty-four blocks are packed in a wooden box.



f. M112 Demolition Charge (Composition C4). This is composition C4 in a new package measuring 1 in. x 2 in. x 12 in. Each block has an adhesive compound on one face. Further information is not available.

g. M118 Demolition Charge. The M118 charge is composed of PETN and plasticizers. The detonating rate is approximately 23,000 ft. per second. Each package contains four sheets ¼ in. x 3 in. x 12 in. Each sheet has an adhesive compound on one face. Further information is unavailable.

h. Composition B. Composition B is a high explosive with a relative effectiveness higher than TNT, and more sensitive.

Because of its high dentonation rate and shattering power, it is used in certain bangalore torpedoes and in shaped charges.

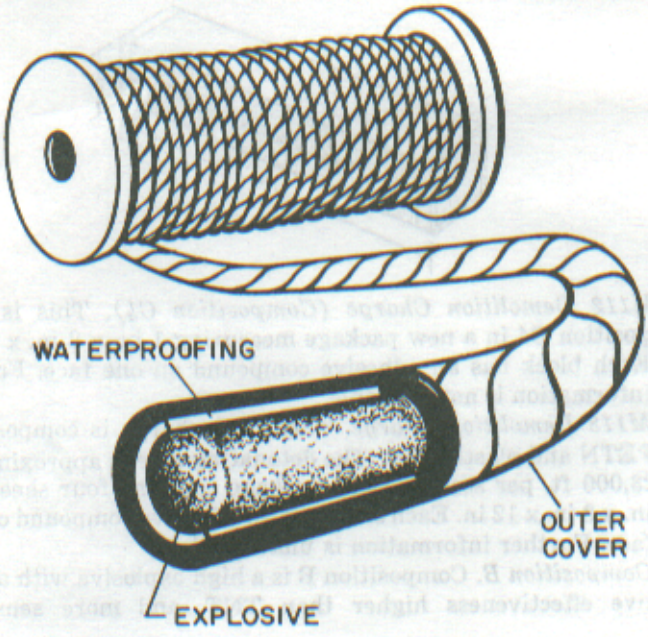
i. PETN. This is used in detonating cord. It is one of the most powerful military explosives, almost equal to nitroglycerine and RDX. In detonating cord, PETN has a velocity rate of 21,000 feet per second.

j. Amatol. Amatol, a mixture of ammonium nitrate and TNT, has a relative effectiveness higher than that of TNT. Amatol (80/20) is used in the bangalore torpedo.

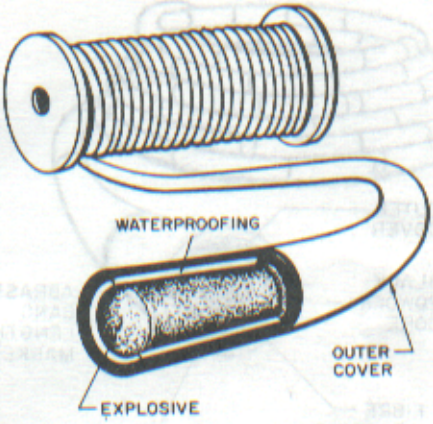
k. RDX. This is the base charge in the M6 and M7 electric and nonelectric blasting caps. It is highly sensitive, and has a shattering effect second only to nitroglycerine.

l. Detonating Cord.

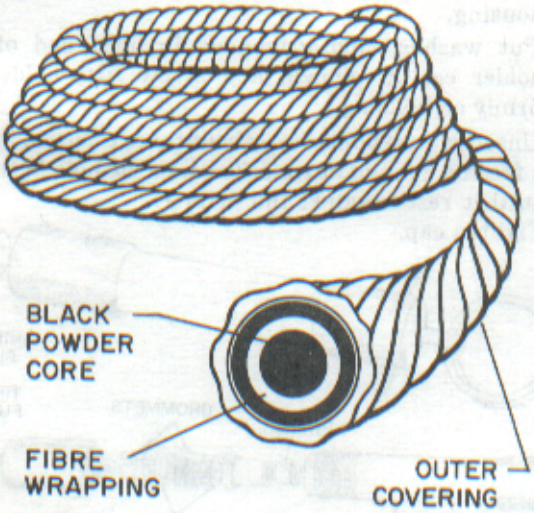
(1) *Types I and II.* These consist of a flexible braided seamless cotton tube filled with PETN. On the outside is a layer of asphalt covered by a layer of rayon with a wax gum composition finish. Type II has the larger diameter and greater tensile strength.



(2) *Type IV.* This is similar to types I and II, except for the special smooth plastic covering designed for vigorous use and rough weather.

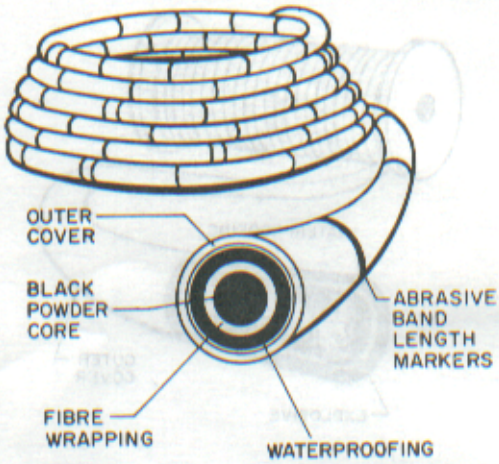


m. Blasting Time Fuse. This consists of black powder tightly wrapped in layers of fabric and waterproofing materials. It may be any color, orange being the most common. As burning rate varies from about 30 to 45 seconds per foot, each roll must be tested before using by burning and timing a 1-foot length.



n. Safety Fuse M700. This fuse is a dark green cord with a plastic cover, either smooth or with single pointed abrasive bands around the outside at 1-foot or 18-inch intervals and double

painted abrasive bands at 5-foot or 90-inch intervals. Although the burning rate is uniform (about 40 seconds per foot), it should be tested before using by burning and timing a 1-foot length.



o. *M60 Fuse Lighter.*

(1) *To install: Unscrew the fuse holder cap, remove shipping* plug, insert time fuse, and tighten cap.

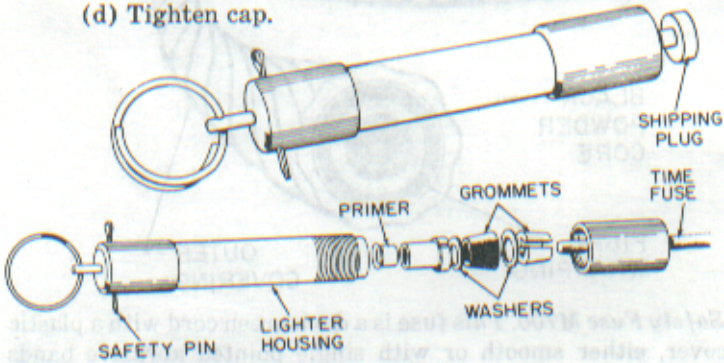
(2) *To reload:*

(a) Insert primer base and primer in end of lighter housing.

(b) Put washers and grommets in open end of fuse holder cap as shown, and screw fuse holder cap firmly on housing.

(c) Unscrew fuse holder cap about three turns and insert a freshly cut end of time fuse into the hole in the cap until it rests against the primer.

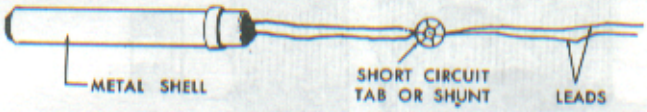
(d) Tighten cap.



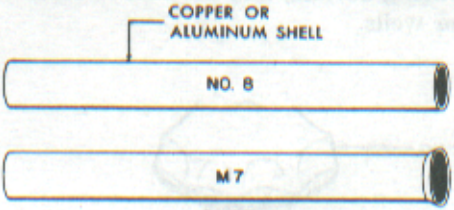
(3) *To fire:*
(a) Remove safety pin
(b) Pull on pull ring.

Note. Lighter is reusable after the insertion of a new primer and the reassembly of parts.

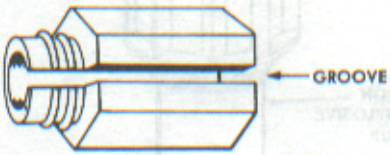
p. Electric Blasting Caps. Electric blasting caps have three lengths of leads—short (4 to 10 ft.), medium (12 to 14 ft), and long (50 to 100 ft). The short-circuit tab or shunt prevents accidental firing. It must be removed before the cap is connected in the firing circuit. Military blasting caps are required to insure detonation of military explosives.



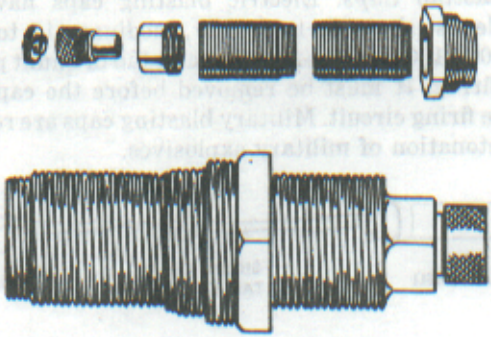
q. Nonelectric Blasting Caps. Two types are available, the No. 8 and the special M7, which resembles the No. 8 in appearance except for the expanded open end.



r. Priming Adapter. This is a plastic device with a threaded end for securing electric and nonelectric primers in the threaded cap wells of military explosives. A groove for easy insertion of the electric lead wires extends the full length of the adapter.



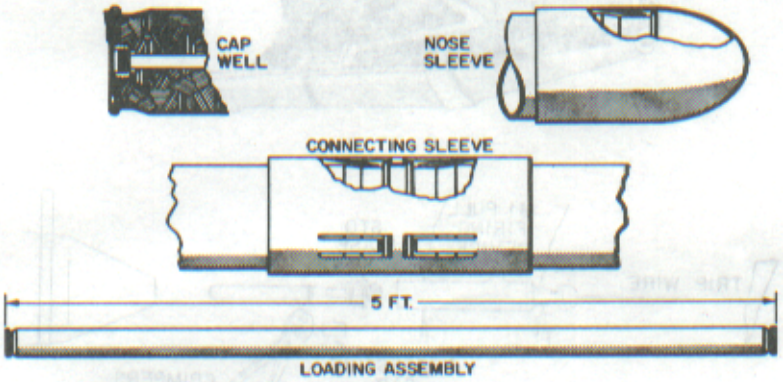
s. *M10 Universal Destructor.* The destructor is used to convert loaded projectiles, missiles, and bombs into improvised charges. The destructor has booster caps containing tetryl pellets. All standard firing devices with the standard base coupler screw into the top.

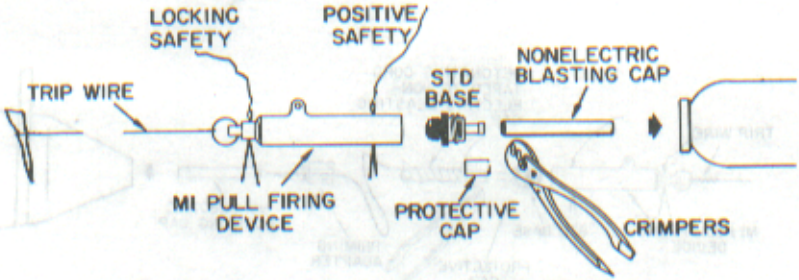


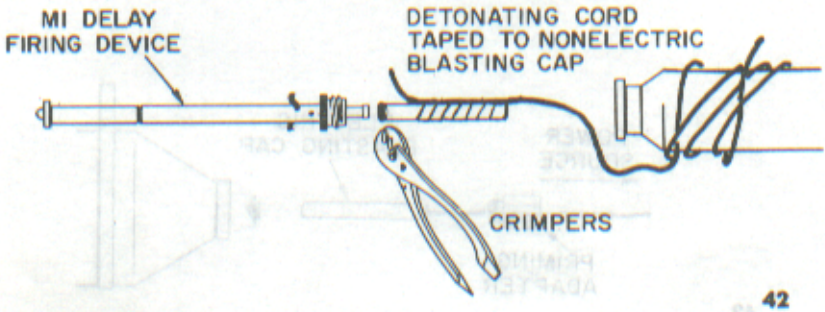
t. *Antitank Mine Activator.* This is a detonator designed for boobytrapping antitank mines. The top is threaded to receive all standard firing devices, and the base to screw in antitank mine activator wells.

28. Bangalore Torpedo

The bangalore torpedo is a group of 10 loading assemblies (steel tubes filled with high explosive) with nose sleeve and connecting sleeves. The loading assemblies may be used singly, in series, or in bundles. They are primed in four ways: by a standard firing device; a standard firing device, nonelectric blasting cap, length of detonating cord, priming adapter, and nonelectric blasting cap (para 29); a standard firing device, and length of detonating cord attached by the clove hitch and two extra turns around the cap well at either end of the loading assembly; and electrical methods (para 29).

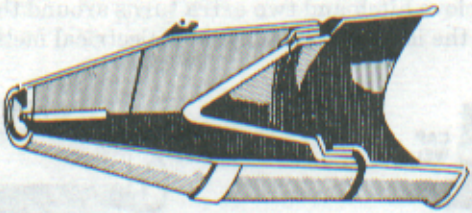


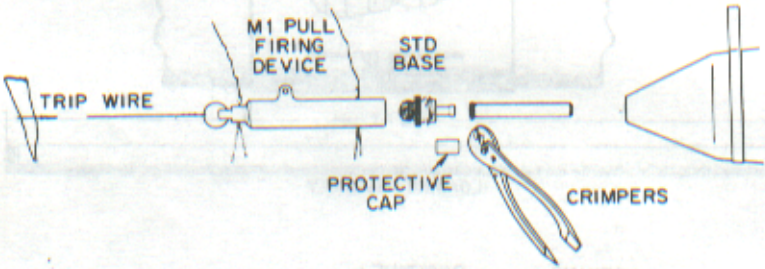


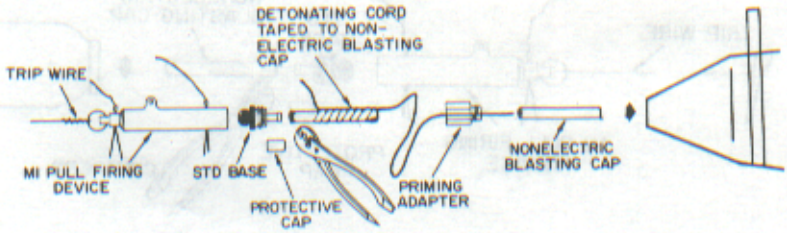


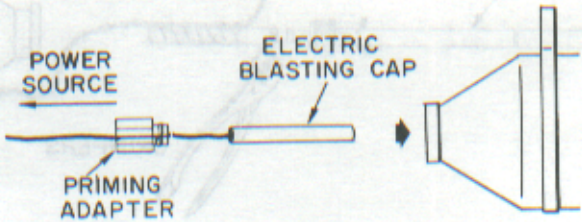
29. M2A3 Shaped Charge

This charge consists of a conical top, conical liner, integral stand-off, threaded cap well, and 11½ pounds of explosive. It may be primed in three ways: by a standard firing device; a standard firing device, nonelectric blasting cap, length of detonating cord, priming adapter, and nonelectric blasting cap; and a priming adapter and electric blasting cap connected to power source.



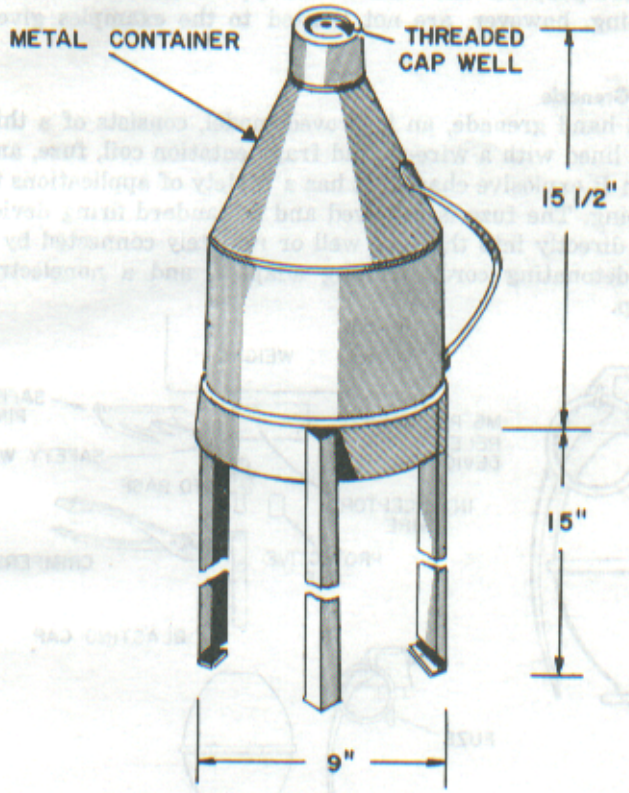






30. M3 Shaped Charge

The M3 shaped charge is a metal container with a conical top, conical liner, threaded cap well, 30 pounds of explosive, and a metal tripod standoff. It may be primed in the same manner as the M2A3 shaped charge above.

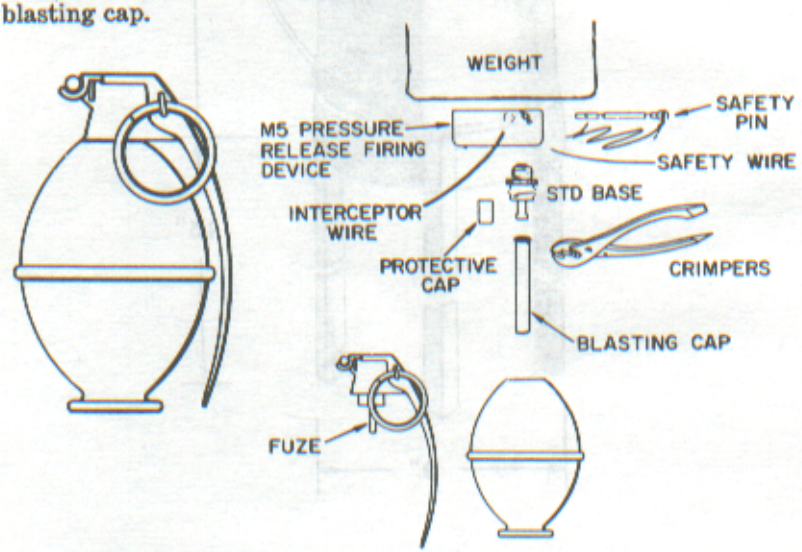


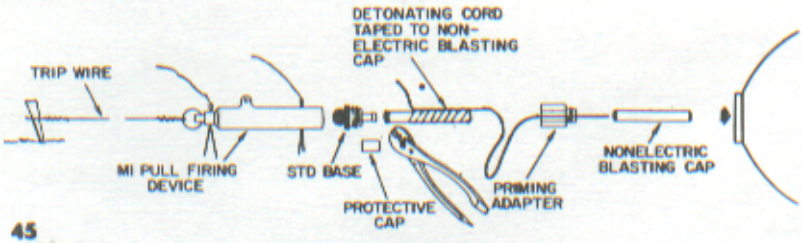
31. Introduction

Hand grenades, bombs, and mortar and artillery ammunition have wide application as improvised explosive charges. The only portion of these useful in boobytrapping, however, are the container and its explosive filler. The fuze is replaced by a standard firing device and an M10 universal destructor—an adapter designed especially for this purpose. The number and type of missiles useful in boobytrapping, however, are not limited to the examples given below.

32. Hand Grenade

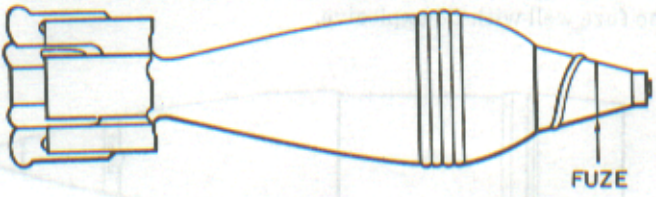
The M26 hand grenade, an improved model, consists of a thin metal body lined with a wire-wound fragmentation coil, fuze, and composition B explosive charge. It has a variety of applications to boobytrapping. The fuze is removed and a standard firing device is screwed directly into the fuze well or remotely connected by a length of detonating cord, priming adapter, and a nonelectric blasting cap.

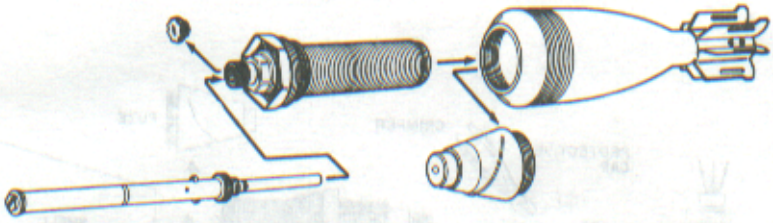


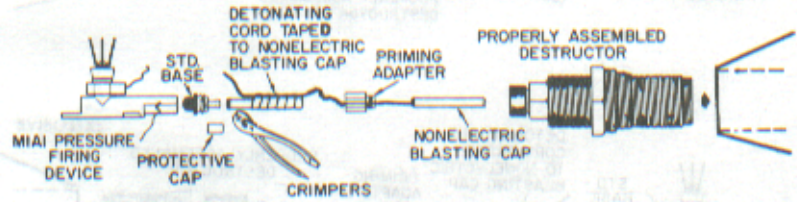


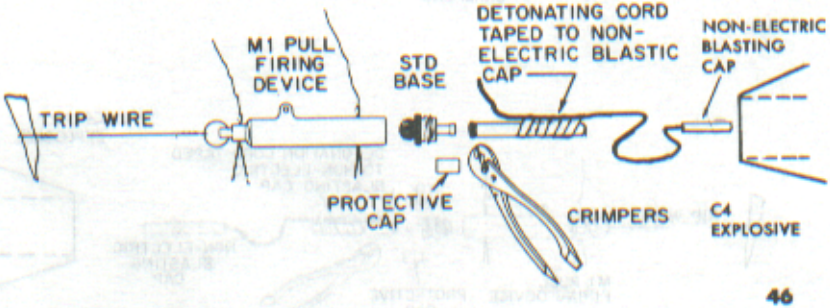
33. 81MM Mortar Shell

This is converted by replacing the fuze with a standard firing device and a properly assembled destructor or by a firing device, length of detonating cord, priming adapter, nonelectric blasting cap, and a properly assembled destructor. If a destructor is not available the detonating cord and nonelectric blasting cap are packed firmly in the fuze well with C4 explosive.



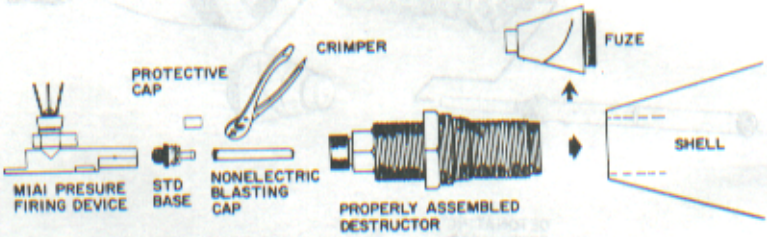


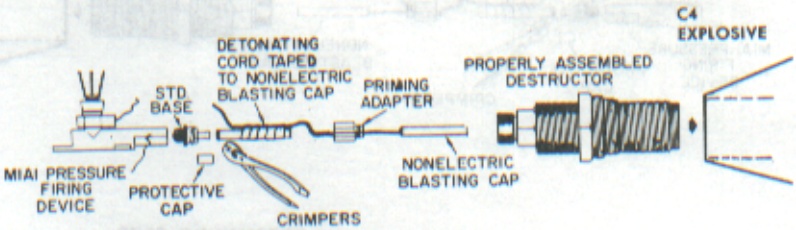


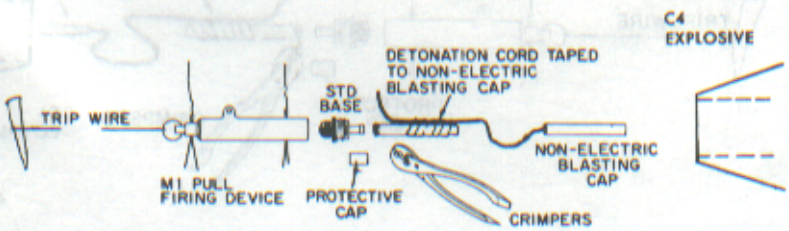


34. High Explosive Shell

The high explosive shell is readily adapted to boobytrapping. The fuze is removed and replaced by a standard firing device and a properly-assembled destructor or a standard firing device, length of detonating cord, priming adapter, nonelectric blasting cap, and a properly-assembled destructor. If a destructor is not available, the detonating cord and nonelectric blasting cap are packed firmly in the fuze well with C4 explosive.

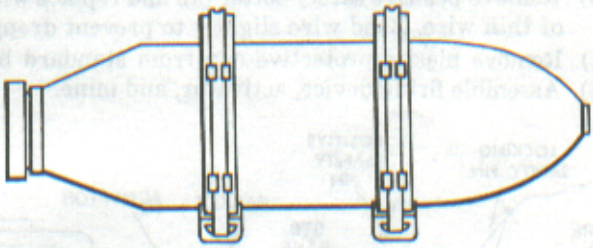


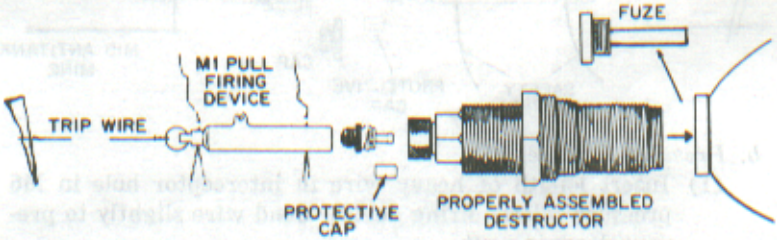


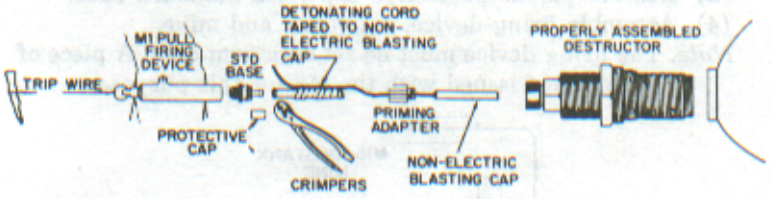


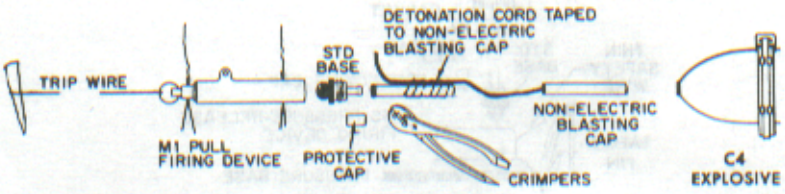
35. Bombs

These are adapted to boobytrapping in the same manner as high explosive and mortar shells. They are primed by replacing the fuze with a standard firing device and a properly-assembled destructor, or with a standard firing device, length of detonating cord, priming adapter, nonelectric blasting cap, and a properly-assembled destructor. If a destructor is not available, the detonating cord and blasting cap are packed firmly in the fuze well with C4 explosive.









36. Antitank Mines

A land mine may be used as the main charge in a boobytrap by removing the fuze and attaching a standard pull or pressure-release firing device in an auxiliary fuze well.

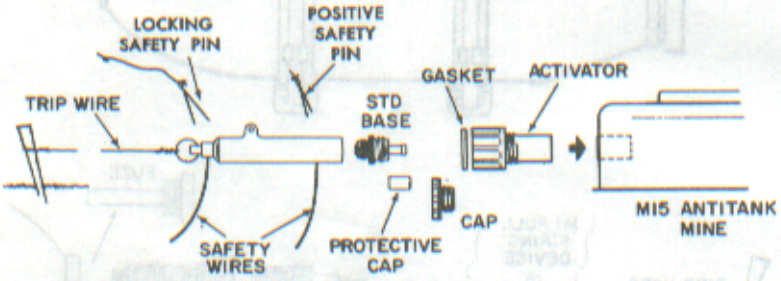
a. Pull.

(1) Remove locking safety cotter pin in M1 pull firing device and replace with length of thin wire. Bend wire slightly to prevent dropping out.

(2) Remove positive safety cotter pin and replace with length of thin wire. Bend wire slightly to prevent dropping out.

(3) Remove plastic protective cap from standard base.

(4) Assemble firing device, activator, and mine.



b. Pressure-Release.

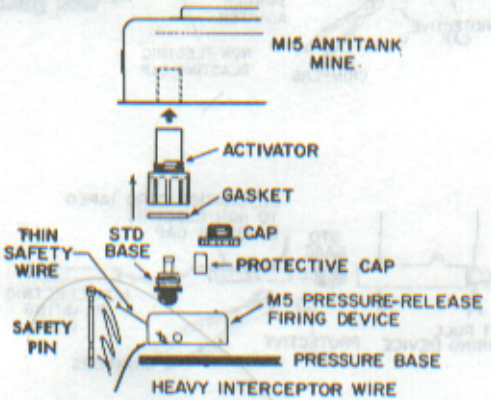
(1) Insert length of heavy wire in interceptor hole in M5 pressure-release firing device. Bend wire slightly to prevent dropping out.

(2) Withdraw safety pin and replace with length of thin wire. Bend wire slightly to prevent dropping out.

(3) Remove plastic protective cap from standard base.

(4) Assemble firing device, activator, and mine.

Note. The firing device must be set on a firm base. A piece of masonite is issued with the M5 for this purpose.



CHAPTER 4

CONSTRUCTION TECHNIQUES

Section I. Boobytrapping Mines in Minefields

37. Tactical Purpose

Antitank mines laid in mine fields are boobytrapped (or activated) primarily to make breaching and clearing as dangerous, difficult, and time consuming as possible in order to confuse, demoralize, and delay the enemy. Most standard U.S. antitank mines and many foreign antitank mines have auxiliary fuze wells for this purpose. See FM20-32 for more detailed information.

38. Methods

U.S. standard antitank mines are generally boobytrapped by means of a pull or a pressure-release firing device, or both, if desirable.

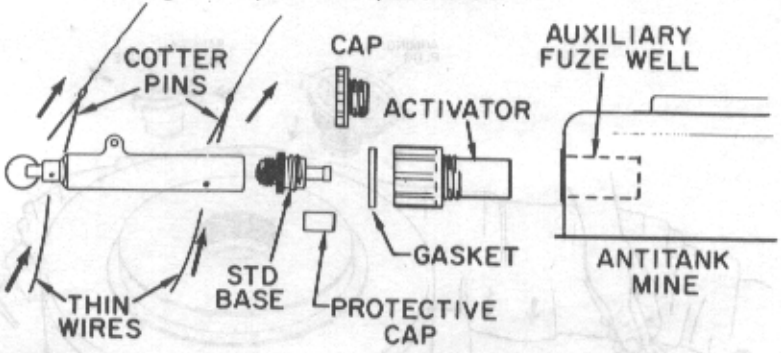
a. Pull. Dig hole to proper depth to bury mine on firm foundation with top of pressure plate even with or slightly above ground level. Arm mine before boobytrapping.

(1) *Installing.*

(a) Remove locking safety cotter pin and replace with length of thin wire. Bend wire slightly to prevent dropping out.

(b) Remove positive safety cotter pin and replace with length of thin wire. Bend wire slightly to prevent dropping out.

(c) Remove protective cap from standard base and assemble firing device, activator, and mine.



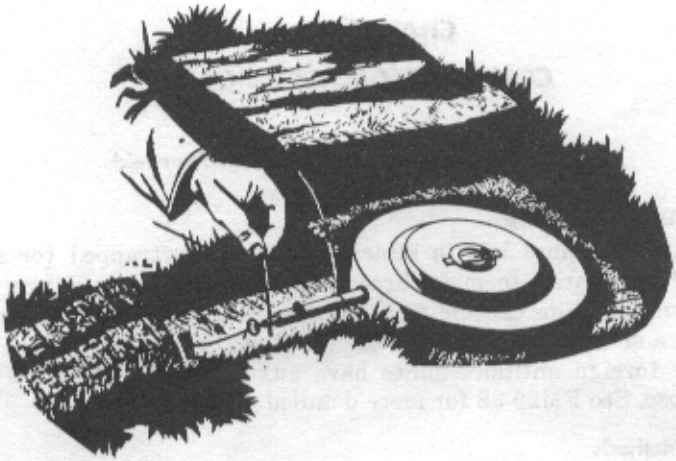
(2) *Arming.*

(a) Anchor one end of trip wire to stake and fasten the other to pull ring.

(b) *Remove locking safety wire first.*

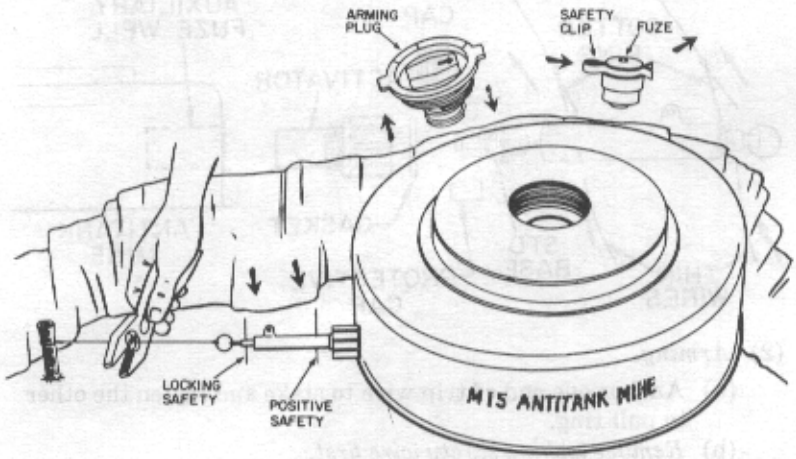
(c) Remove positive safety *last.*

(d) Camouflage.



(3) *Disarming.*

(a) Uncover mine carefully.
(b) Locate boobytrap assembly.
(c) Replace positive safety *first*, then locking safety.
(d) Cut trip wire.
(e) Turn arming dial of mine to *safe* and remove arming plug.
(f) Remove fuse and replace safety clip.
(g) Replace arming plug.
(h) Recover mine and firing device.



b. Pressure-Release. Dig hole to proper depth to bury mine on firm foundation, with top of pressure plate even with or slightly above ground level.

(1) *Installing.*

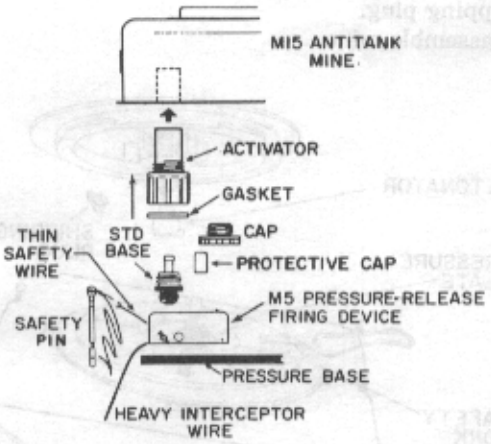
(a) Insert length of heavy wire in interceptor hole. Bend wire slightly to prevent dropping out.

(b) Remove safety pin. Apply pressure on release plate until pin comes out easily.

(c) Insert length of light wire in safety pin hole and bend slightly to prevent dropping out.

(d) Remove protective cap from standard base and assemble firing device, activator, and mine.

(e) Place mine and firing assembly in hole, using pressure board to insure a solid foundation for firing device.

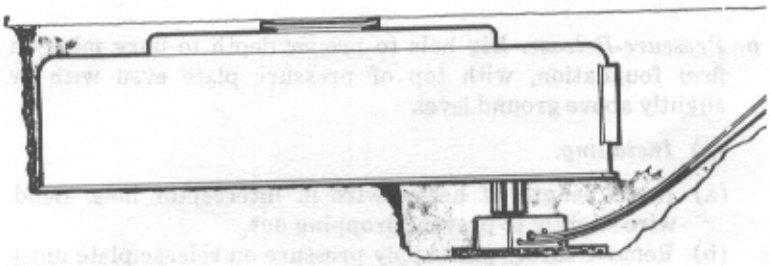


(2) *Arming.*

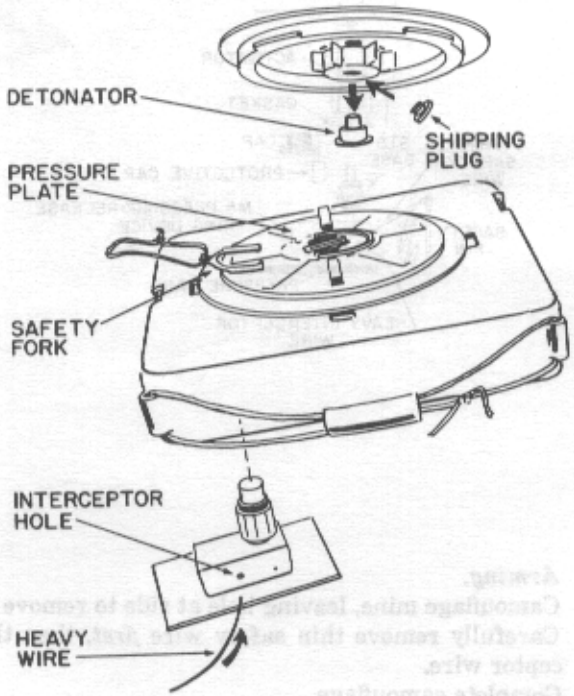
(a) Camouflage mine, leaving hole at side to remove safeties.

(b) Carefully remove thin safety wire *first*, then the interceptor wire.

(c) Complete camouflage.



(3) *Disarming.*
(a) Uncover mine carefully.
(b) Locate boobytrap assembly.
(c) Insert length of heavy wire in interceptor hole.
(d) Turn dial on pressure plate to "S" (safe) and replace safety fork.
(e) Recover mine and firing device assembly.
(f) Remove pressure plate, unscrew detonator, and replace shipping plug.
(g) Reassemble mine.



39. Boobytrapped Foreign Mines

a. Antitank Mines.

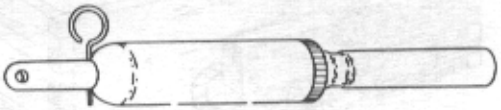
The Communist European and Asiatic armies boobytrap mines in a much different fashion from that of the U.S. and other NATO countries. The Germans in World War II used both special antilift devices and antidisturbance fuzes, one of which has been copied by the French.

(1) *Antilift devices.*

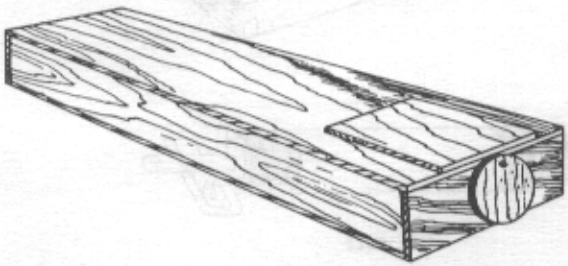
(a) Russia

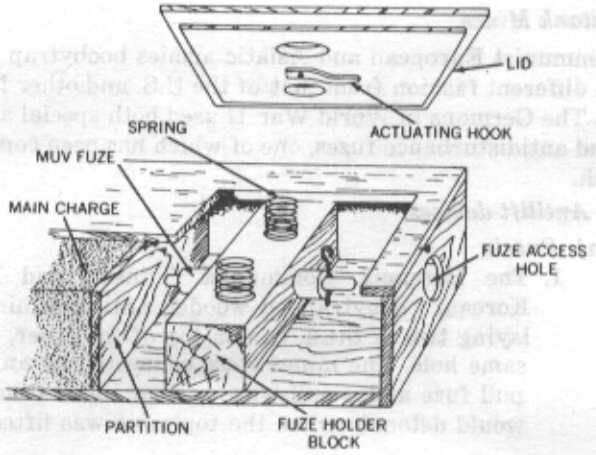
1. The Russians, Communist Chinese, and North Koreans boobytrapped wooden antitank mines by laying two of them, one on top of the other, in the same hole. The mines were connected by an MUV pull fuze and a pull wire, so that the bottom mine would detonate when the top mine was lifted.

2. The Russians in World War II also had a more sophisticated method—a special wooden antilift device, placed under the mine. This, however was readily located by probing. It consisted of an outer case, a charge, an MUV pull fuze, a pressure release lid supported on two coil springs, and a fuze access hole. Lifting the mine initiated the antilift. *This device is too dangerous to disarm.* Even though the pressure-release might be secured by a rope or length of wire, the chances of additional pull wires and boobytrap charges are too great to risk. Also deterioration of the wooden case from prolonged burial adds to the difficulty. *The best procedure is to blow all wooden antitank mines and antilifts in place.*

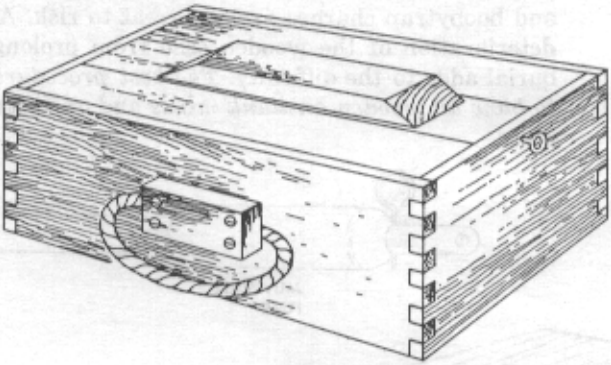


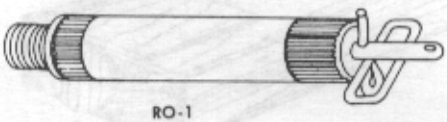
MUV PULL FUZE



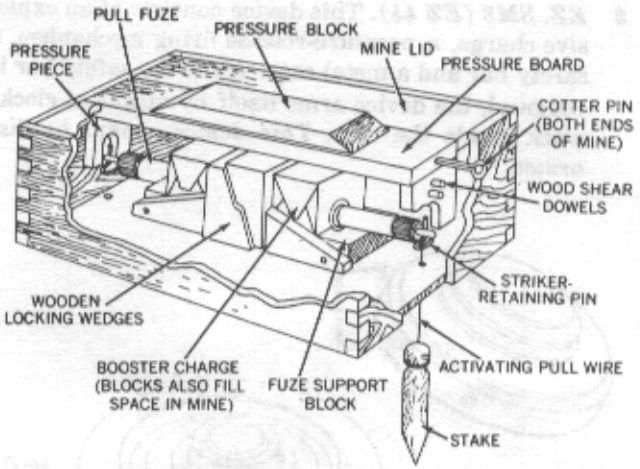


(b) Czechoslovakia. This satellite country has a wooden antitank mine (PT-Mi-D) that may prove extremely hazardous to breaching and clearing parties. Having an RO-1, pull fuze in each end, it is easily boobytrapped by means of wire anchored to a stake underneath the mine and extended through a hole in the bottom of the case to the fuze pull pin.



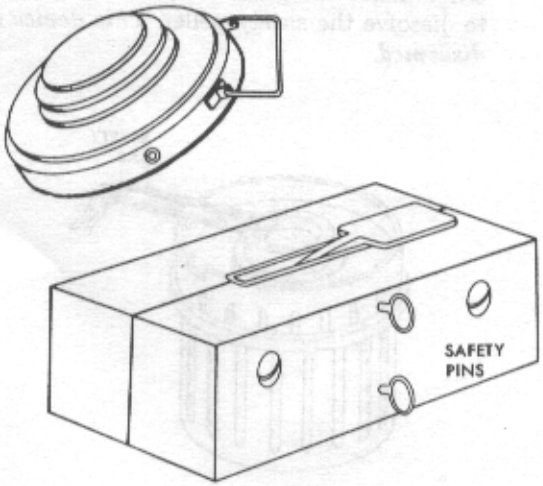


RO-1
PULL FUZE

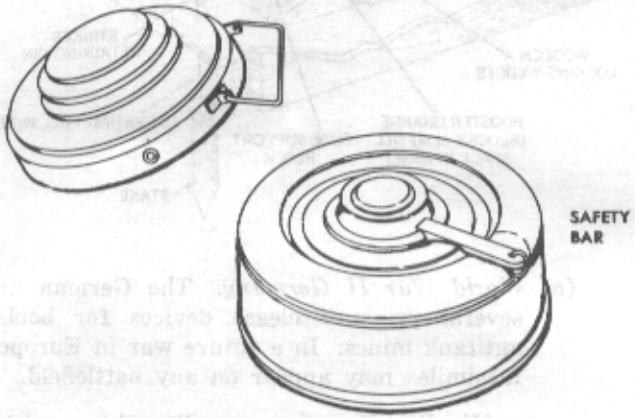


(*c*) *World War II Germany.* The German armies had several pressure-release devices for boobytrapping antitank mines. In a future war in Europe, these or facsimiles may appear on any battlefield.

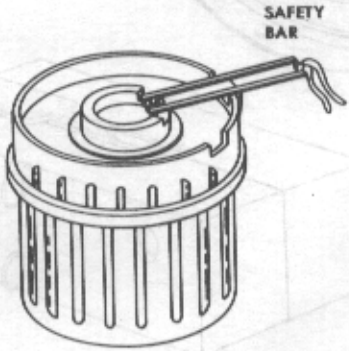
1 *Nipolite all explosive antilift.* This consisted of two oblong blocks of moulded explosive joined together with brass bolts and recessed to contain the metal striker assembly. It may be disarmed by inserting a safety in the lower safety pin hole.



2 *EZ. SM2 (EZ 44).* This device consists of an explosive charge, a pressure-release firing mechanism, a safety bar and a metal case. When the safety bar is removed, the device arms itself by means of clockwork inside the case. *This device cannot be disarmed.*

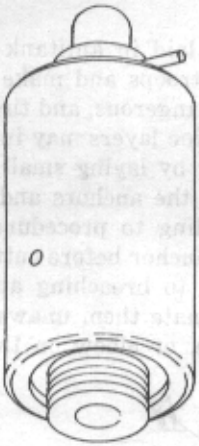


3 *SF3.* This antilift consists of an explosive charge, pressure-release striker assembly, safety bar, and chemical arming equipment. A turn of the safety bar crushes the glass vial, releasing the chemical to dissolve the safety pellet. *This device cannot be disarmed.*

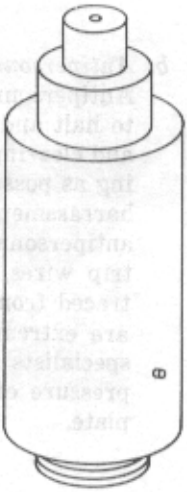


(2) *T. Mi. Z 43 and T. Mi Z 44 antidisturbance fuzes.*

(*a*) *Germany.* In addition to several antilift devices, the Germans developed two antidisturbance fuzes initiated by pressure or pressure-release for activating Teller mines 42 and 43. To arm, the fuze is placed in the fuze well and the pressure plate screwed down on top of the fuze, shearing the arming pin. Removal of the pressure plate initiates the pressure-release mechanism and detonates the mine. Although the T. Mi. Z 44 was an experimental model that never reached the field, copies of both fuzes are now in use in several European armies. *Mines armed with these fuzes can neither be identified by size, shape, marking, or color of the case, nor be disarmed.*

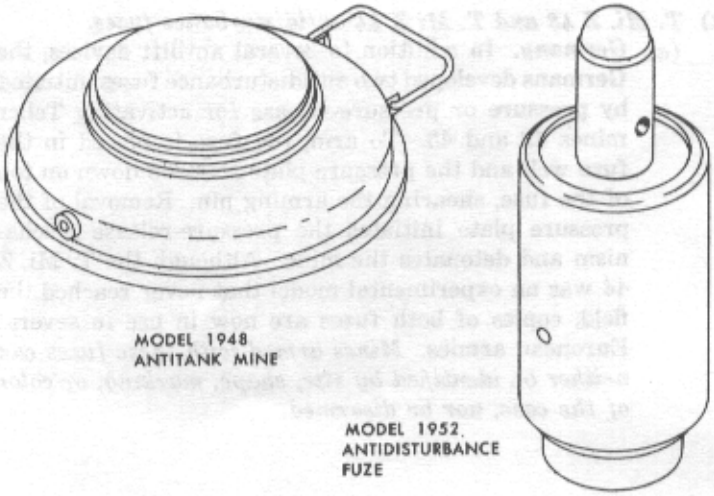


T Mi. Z. 43



T. Mi. Z 44

(*b*) *France.* The French have a copy of the T. Mi. Z 43 antidisturbance (pressure and pressure-release) fuze, and Teller mine 43, named models 1952 and 1948 respectively. The fuze is placed in the fuze well and the pressure plate screwed down on top, shearing the arming pin. Removing the pressure plate actuates the pressure-release element, detonating the mine.

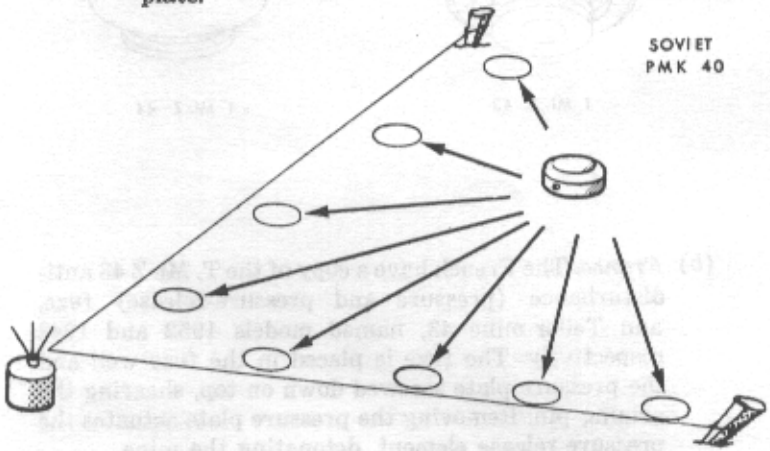


MODEL 1948
ANTITANK MINE

MODEL 1952
ANTIDISTURBANCE
FUZE

b. Antipersonnel Mines.

Antipersonnel mines are laid in antitank minefields to halt and delay enemy troops and make breaching and clearing as difficult, dangerous, and time consuming as possible. Enemy mine layers may increase this harrassment substantially by laying small blast type antipersonnel mines near the anchors and along the trip wires, which, according to procedure, must be traced from pull ring to anchor before cutting. These are extremely hazardous to breaching and clearing specialists who may detonate them unawares by the pressure of a hand, knee, or elbow on the pressure plate.



SOVIET
PMK 40

Section II. BOOBYTRAPPING BUILDINGS

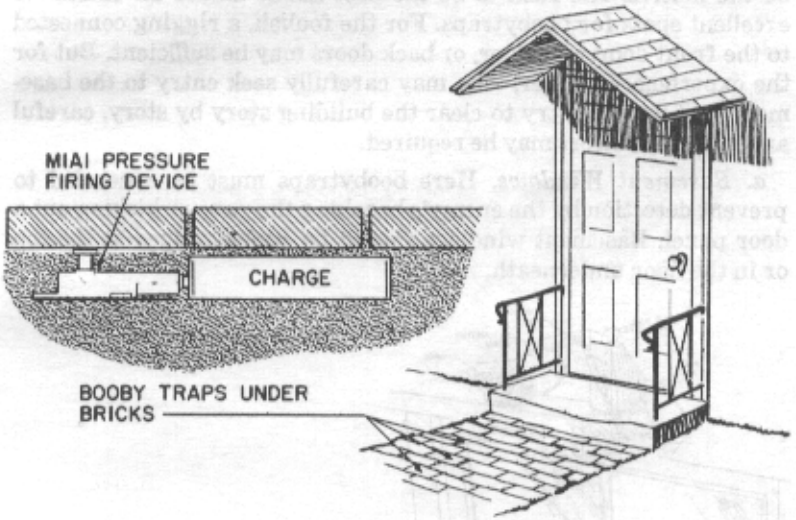
40. Advantages

Boobytraps laid in buildings and their surroundings can be very effective. Buildings are very attractive to fighting men for they provide a degree of comfort and shelter from the elements. They are also useful for headquarters where plans may be made and communications carried on with greater dispatch.

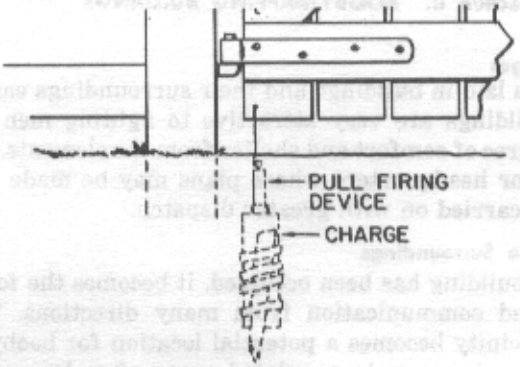
41. Immediate Surroundings

a. Once a building has been occupied, it becomes the focal point for travel and communication from many directions. Thus the immediate vicinity becomes a potential location for boobytraps.

b. Dwellings in sparsely populated areas often have out buildings, wood piles, fruit trees, wells, fences with gates, walks, and other locations easily rigged to wound or destroy careless soldiers.



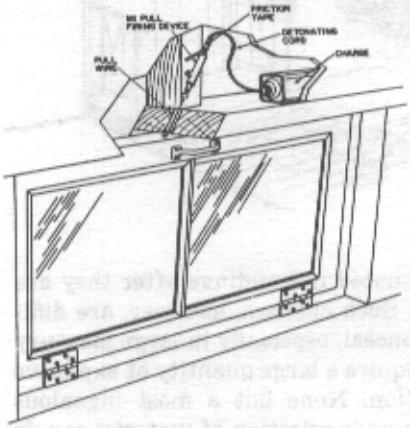
c. Delayed action charges detonated in buildings after they are occupied are extremely effective. Such charges, however, are difficult if not almost impossible to conceal, especially in large masonry and steel buildings, which may require a large quantity of explosive for serious damage or destruction. None but a most ingenious specialist, given time, help, and a wide selection of material can do this satisfactorily. In World War II, the Russians prepared such a boobytrap for the Germans. However, after long careful search, the charge and its clockwork fuze were located by means of a stethoscope. Small buildings, on the other hand, may be only moderately difficult to destroy by delayed charges.

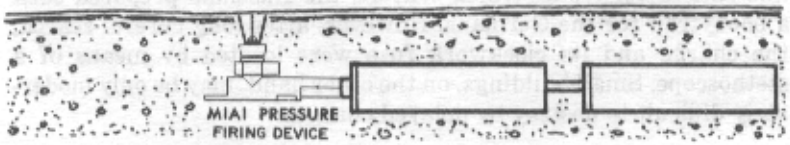


42. Entrances

Curiosity prompts a soldier to investigate hurriedly an interesting building in his path. Women, loot, or mere inquisitiveness may be the motive. His rush to be the first inside makes all entrances excellent spots for boobytraps. For the foolish, a rigging connected to the front door, side door, or back doors may be sufficient. But for the experienced soldier, who may carefully seek entry to the basement first and then try to clear the building story by story, careful and ingenious effort may be required.

a. Basement Windows. Here boobytraps must be concealed to prevent detection by the enemy's breaking the pane or kicking out a door panel. Basement windows should be boobytrapped at the top or in the floor underneath.

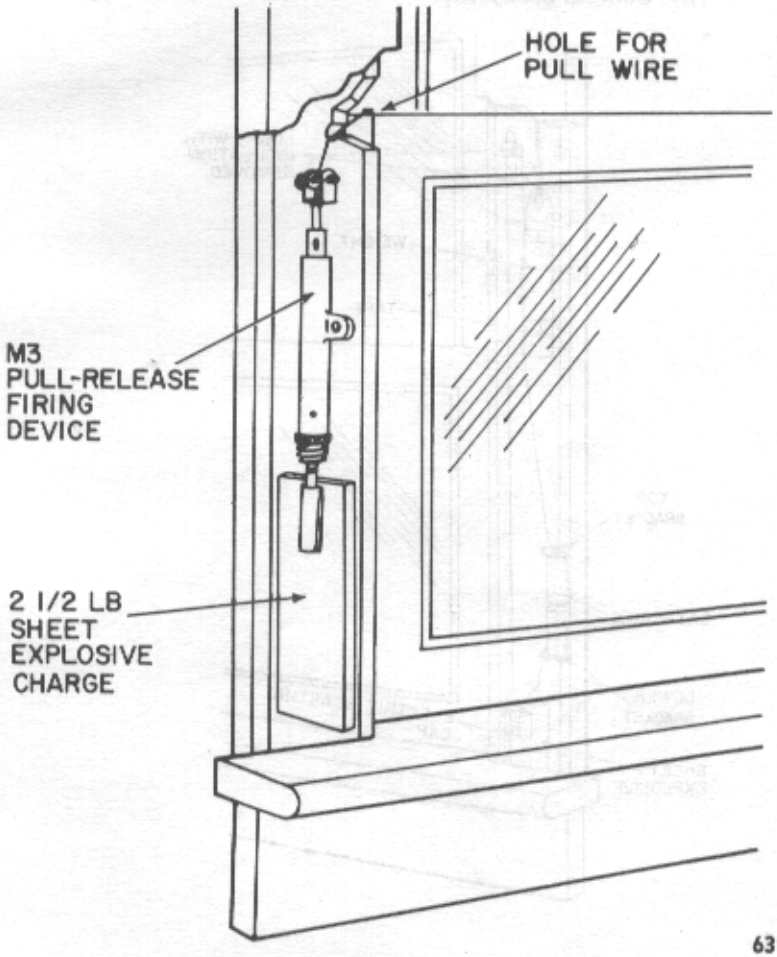




b. Upper Floor Windows. Window charges are easier concealed in the weight box behind the jamb than in the wall or under the floor. Experienced hands can remove and replace window trim without obvious damage.

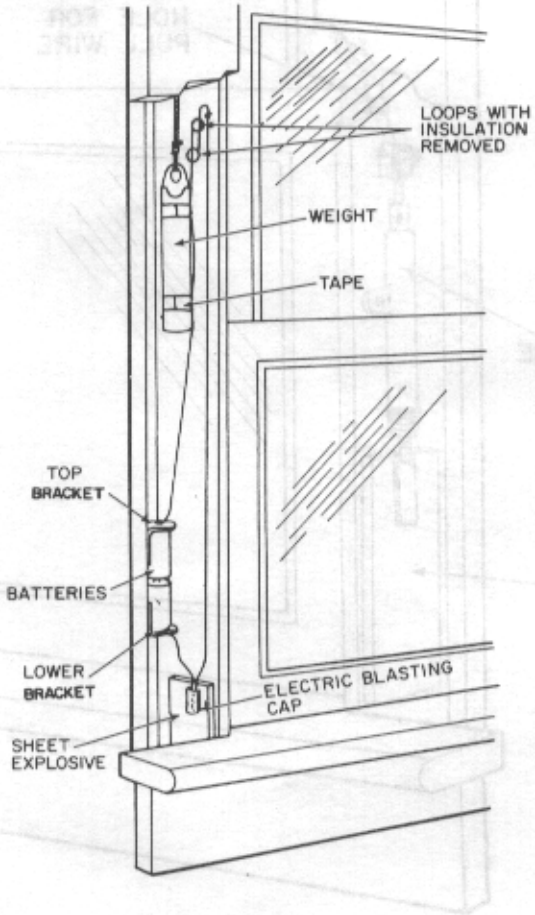
(1) *Nonelectric firing.*

(a) Assemble M3 pull-release firing device, standard base, and blasting cap.
(b) Place sheet explosive in weight box.
(c) Bore hole in side jamb for pull wire.
(d) Anchor one end of pull wire to window, and thread through hole in side jamb.
(e) Attach free end of pull wire to ratchet on firing device.
(f) Arm firing device.
(g) Conceal boobytrap.



(2) *Electric firing.*

(a) Fasten two metal brackets to side of weight box close enough to wedge two flashlight batteries between.
(b) Place sheet explosive charge in weight box.
(c) Insert electric blasting cap in charge.
(*d*) Cut one leg wire and attach to lower bracket.
(e) Cut other leg wire to proper length to twist an uninsulated loop on end and fasten to hang in place just above top of window weight.
(f) On a length of leg wire twist on uninsulated loop around the leg wire hanging above the weight. Thread other end through other uninsulated loop and fasten to top clamp. Tape wire to window weight.
(g) Test circuit with galovonmeter first, then insert batteries between brackets.
(h) Conceal boobytrap.



c. Doors. Improved detection methods have made the use of boobytraps on doors, with charges, firing devices, and wires exposed, a waste of time and material, except for purposes of deception. The best location is the head or side jamb, not the sill, which is often recommended. The sill is exposed, so that one experienced clearing unit may easily locate the rigging while in the jamb, it is concealed by the doorstop.

(1) *Head jamb rigging.*

(a) Assemble M1 pull firing device, standard base, and nonelectric blasting cap.

(b) Assemble length of detonating cord, priming adapter, nonelectric blasting cap and explosive block.

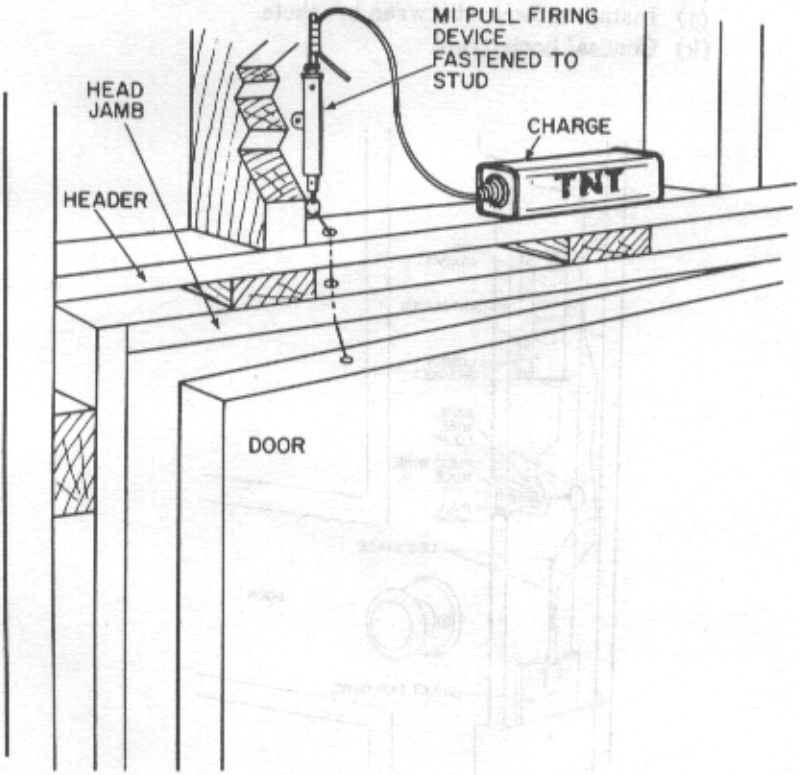
(c) Attach firing device firmly to stud and tape free end of length of detonating cord to nonelectric blasting cap.

(d) Drill hole at proper place in header and head jamb.

(e) Anchor one end of pull wire at proper place on door and thread free end through holes.

(f) Close door and attach pull wire to pull ring.

(g) Arm and conceal boobytrap.



(2) *Side jamb rigging.*

(a) Attach metal brackets to side jamb close enough to wedge two flashlight batteries between.

(b) Insert sheet explosive charge snugly between stud and jamb.

(c) Place electric blasting cap in charge, and fasten one leg wire to top bracket.

(d) Bore pull wire hole at proper spot inside jamb.

(e) Cut other leg wire long enough to twist on an insulated loop on one end and fit over pull wire hole. Loop should be about ½ inch in diameter.

(f) Twist on uninsulated loop on one end of leg wire and secure to lower bracket so that loop fits over pull wire hole. Fasten wire to jamb.

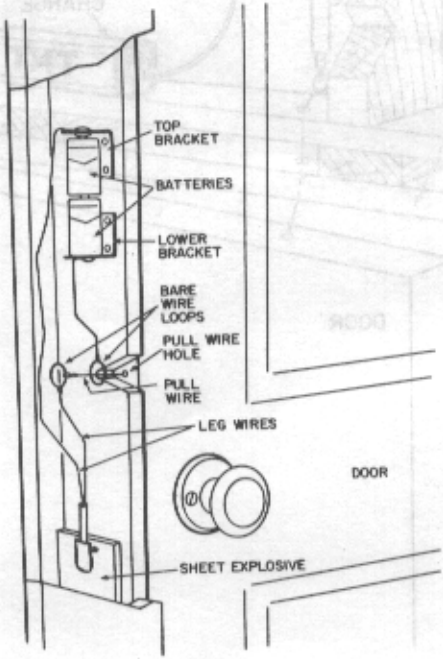
(g) Anchor one end of insulated pull wire at proper spot on door, and thread free end through pull wire hole and loop fastened to jamb.

(h) Close door. Fasten free end of pull wire to other loop to hold it snugly against stud.

(i) Check circuit with galvonometer first, then

(j) Install batteries between brackets.

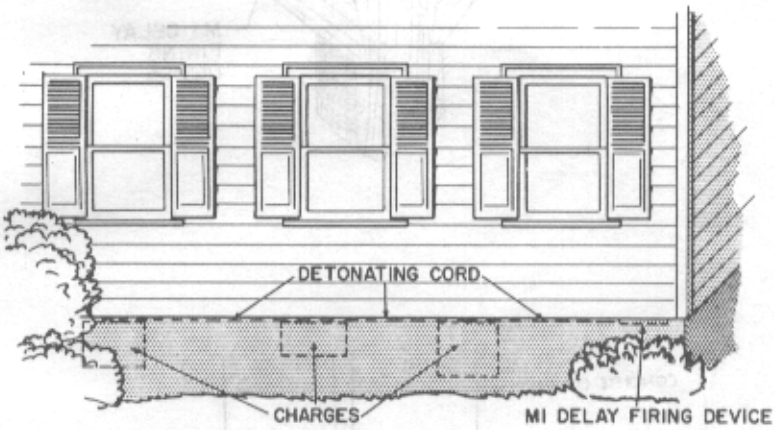
(k) Conceal boobytrap.



43. Structural Framework

a. In a building charges should be placed where detonation will seriously impair its structural strength, such as walls, chimneys, beams, and columns. Charges and firing devices must be carefully concealed to avoid detection.

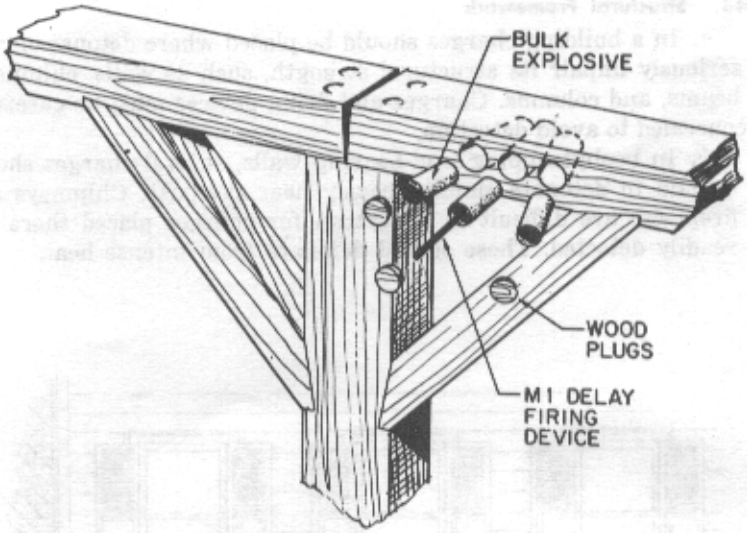
b. In boobytrapping load-bearing walls, several charges should be laid to detonate simultaneously near the base. Chimneys and fireplaces are difficult to boobytrap for charges placed there are readily detected. These should detonate from intense heat.

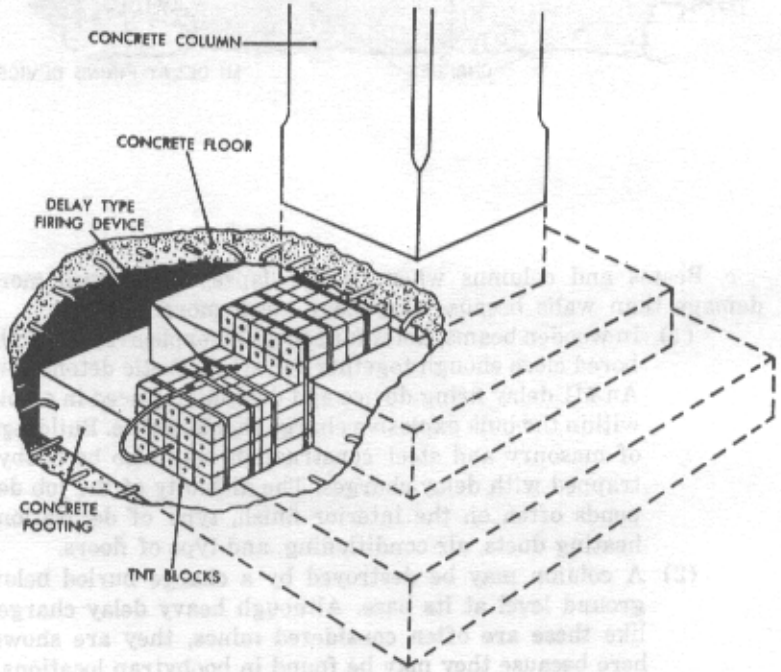


c. Beams and columns when they collapse cause much more damage than walls because they bear much more weight.

(1) In wooden beams, holes for concealed explosives should be bored close enough together for sympathetic detonation. An M1 delay firing device and detonator placed in a hole within the bulk explosive charge should suffice. Buildings of masonry and steel construction may also be boobytrapped with delay charges. The difficulty of the job depends often on the interior finish, type of decoration, heating ducts, air conditioning, and type of floors.

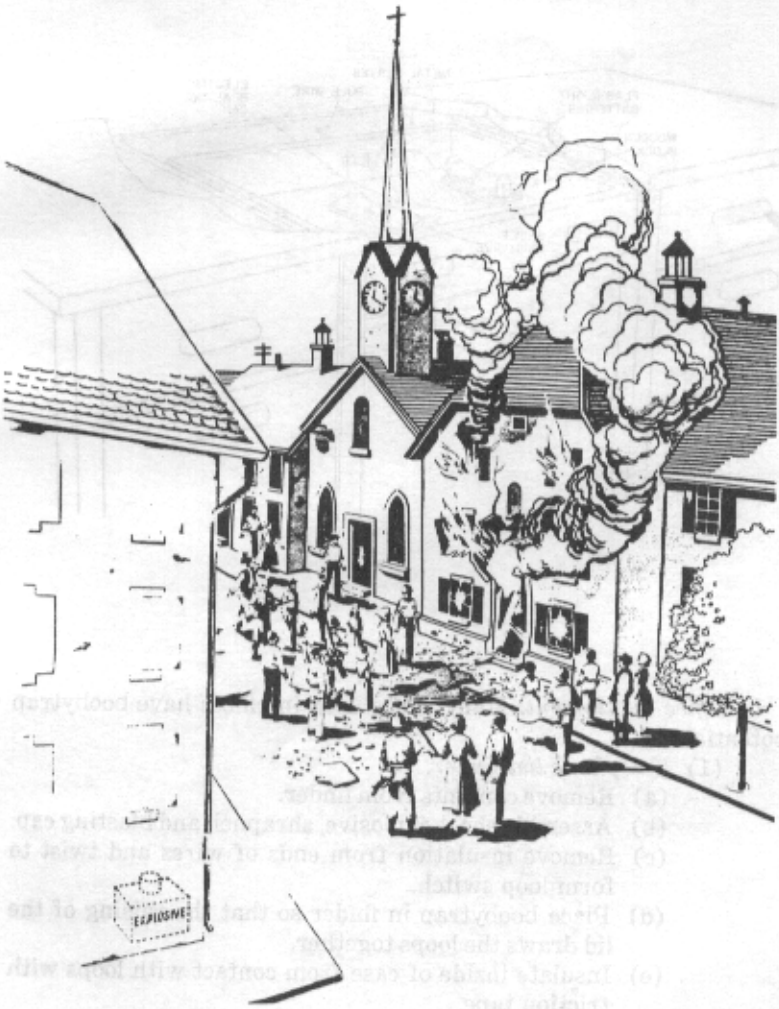
(2) A column may be destroyed by a charge buried below ground level at its base. Although heavy delay charges like these are often considered mines, they are shown here because they may be found in boobytrap locations.


BULK
EXPLOSIVE
WOOD
PLUGS
M1 DELAY
FIRING
DEVICE


CONCRETE COLUMN
CONCRETE FLOOR
DELAY TYPE
FIRING DEVICE
CONCRETE
FOOTING
TNT BLOCKS

d. Loose floor boards sometimes are excellent objects for booby-trapping. The rigging must escape detection, however; otherwise, it will be ineffective. This rigging might be harder to detect if the support underneath is chiseled out to let the floorboard sink about ¼ inch when tramped on.

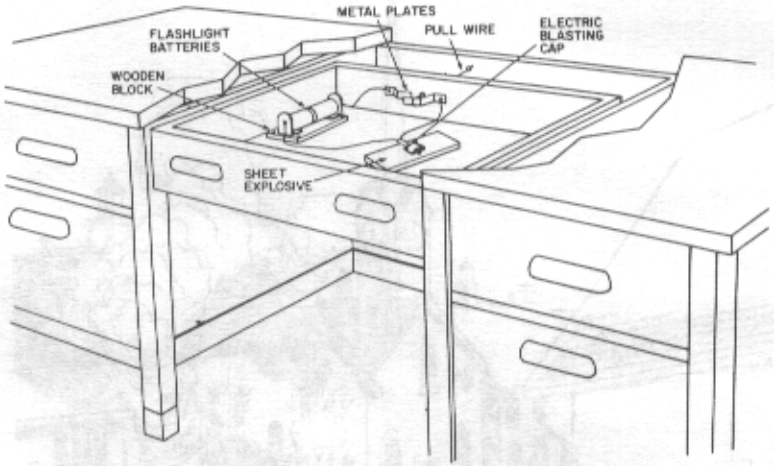
e. A double delay chain detonating boobytrap should be very effective if timed right and skillfully laid. *First,* is the explosive of a minor charge laid in an upper story damaging the building only slightly. *Then,* after a curious crowd has gathered, a second heavy charge or series of charges go off, seriously damaging or destroying the building and killing or wounding many onlookers.



44. Interior Furnishings

Vacated buildings provide much opportunity for boobytrapping. Hurriedly departing occupants usually leave behind such odds and ends as desks, filing cases, cooking utensils, table items, rugs, lamps, and furniture. Electric light and power fixtures are also exploitable.

a. Desk. Because of its construction a desk is easily boobytrapped. If carefully placed the rigging may be nondetectable and if properly constructed, cannot be neutralized. Electric firing systems are the most suitable for this purpose. Sheet explosive is much better than other types, because its adhesive surface holds it firmly in place. Check the circuit with a galvonometer *before* installing the batteries.



b. Office Equipment. Many items used in offices have boobytrap potential.

(1) *Telephone list finder.*

(a) Remove contents from finder.

(b) Assemble sheet explosive, shrapnel, and blasting cap.

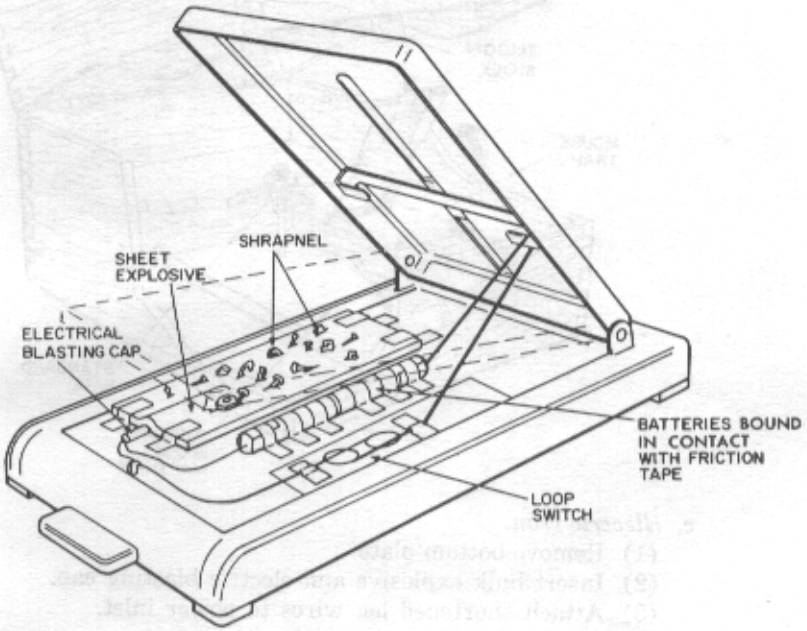
(c) Remove insulation from ends of wires and twist to form loop switch.

(d) Place boobytrap in finder so that the raising of the lid draws the loops together.

(e) Insulate inside of case from contact with loops with friction tape.

(f) Check circuit with galvanometer *first*, then install batteries.

Note. Batteries may be connected to legwires by wrapping them tightly in place with friction tape.



(2) *Card File.* A wooden card file can be boobytrapped effectively by the use of a mousetrap rigged as a trigger, a standard base with blasting cap attached, a support block fastened inside to hold the firing assembly at the proper level for operation, and a trigger block to hold the trigger in armed position.

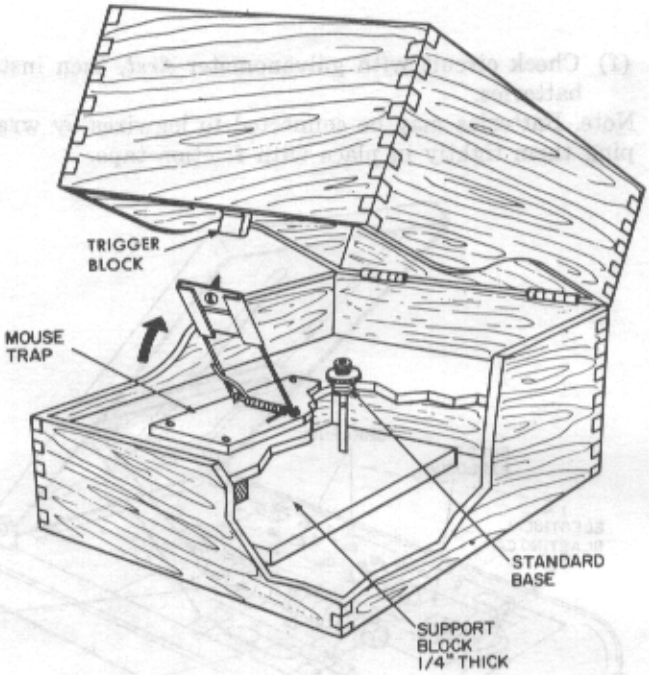
(a) Rig wire trigger of mousetrap with screw and metal strip.

(b) Locate support block on strips at proper level to fix trigger in trigger block.

(c) Bore hole in support block at proper place to admit standard base and blasting cap so that sheet metal screw will strike percussion cap.

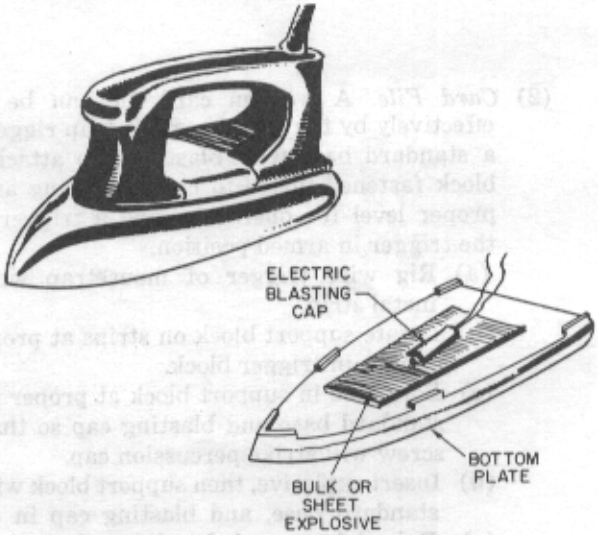
(d) Insert explosive, then support block with mousetrap, standard base, and blasting cap in position.

(e) Raise trigger and close lid so that trigger is fixed in firing position.



c. Electric Iron.

(1) Remove bottom plate.
(2) Insert bulk explosive and electric blasting cap.
(3) Attach shortened leg wires to power inlet.

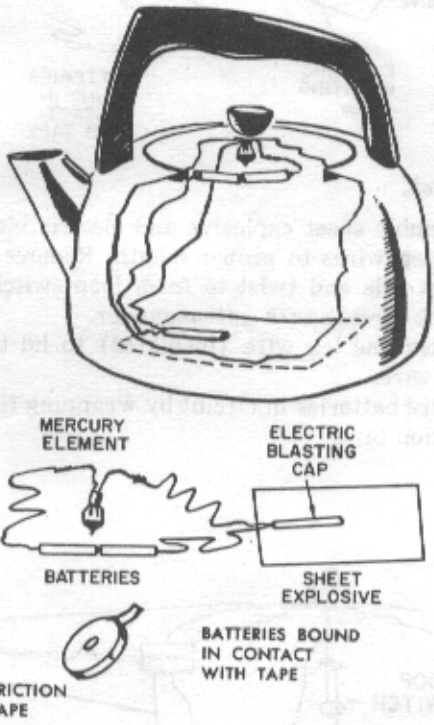


d. Teakettle.

(1) Assemble sheet explosive, electric blasting cap and mercury element in teakettle.

(2) Check circuit with galvanometer first, then install batteries.

Note. Batteries may be bound tightly in circuit with friction tape. For safety and ease of assembly, use a wrist watch delay in circuit (para 60*d*).



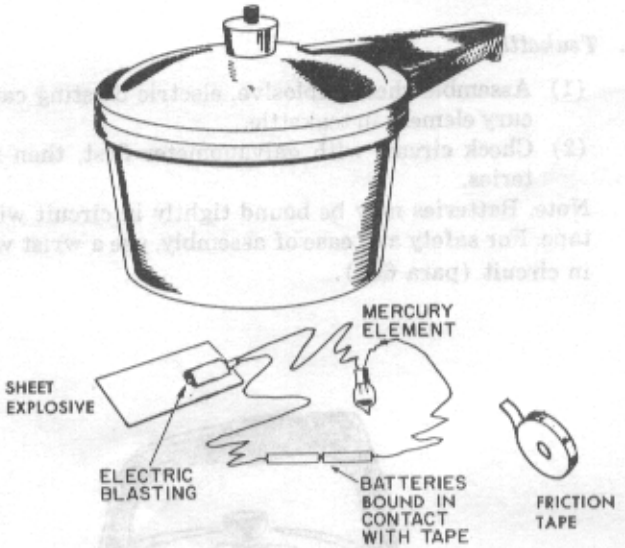
e. Pressure Cooker.

(1) *Antidisturbance circuit.*

(a) Assemble sheet explosive, mercury element, and electric blasting cap in cooker.

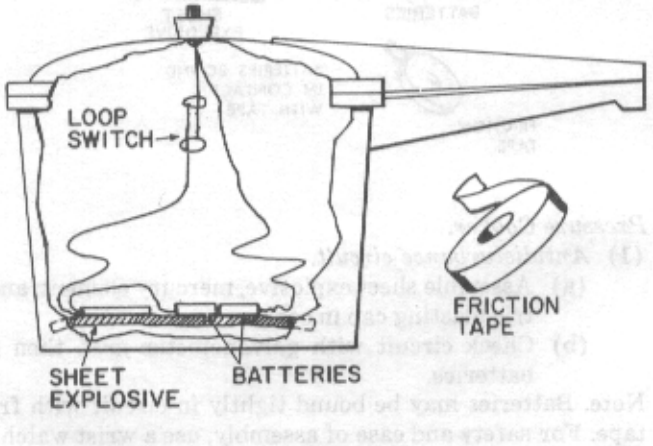
(b) Check circuit with galvanometer *first*, then install batteries.

Note. Batteries may be bound tightly in circuit with friction tape. For safety and ease of assembly, use a wrist watch delay in circuit (para 60*d*).



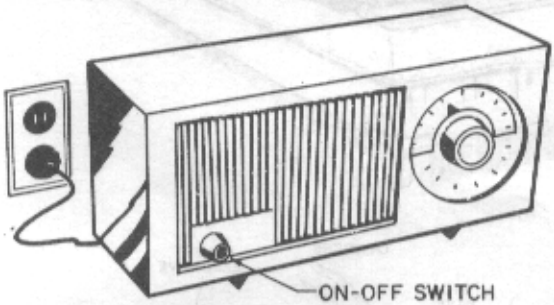
(2) *Loop switch.*

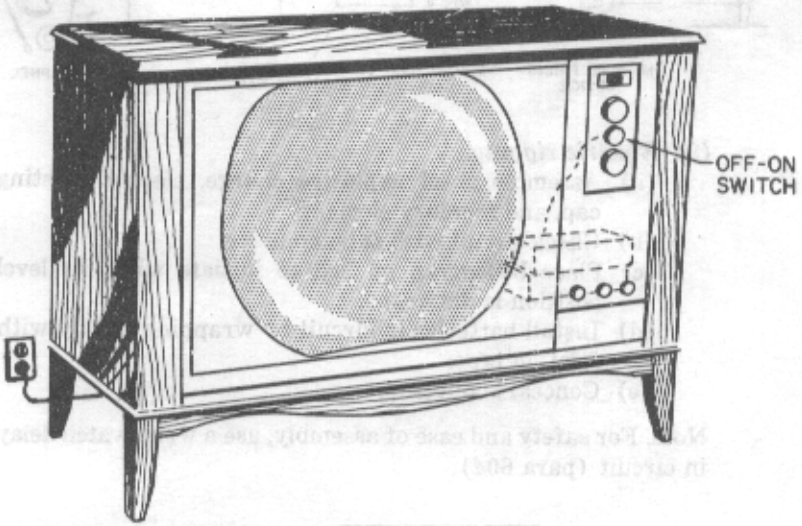
(1) Assemble sheet explosive and electric blasting cap.
(2) Cut leg wires to proper length. Remove insulation from ends and twist to form loop switch.
(3) *Check circuit with galvonometer.*
(4) Fasten one leg wire (insulated) to lid to serve as pull wire.
(5) Secure batteries in circuit by wrapping tightly with friction tape.



f. Radio and Television Sets. Both sets may be boobytraped by assembling a charge and an electric blasting cap inside the case. The leg wires are connected in the circuit for detonation at turning of off-on switch.

Extreme care is required in connecting leg wires to prevent premature explosion.





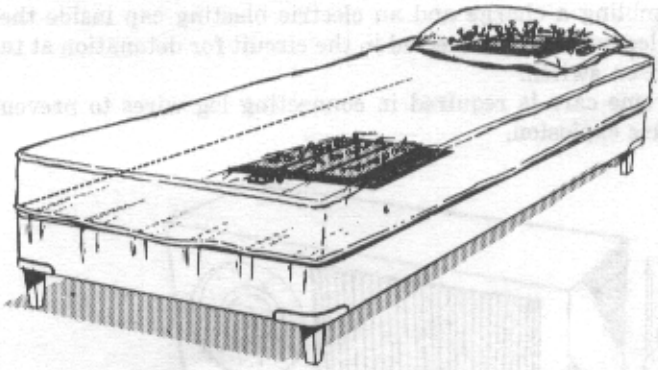
g. Bed. Two methods may be used—a charge, nonelectric blasting cap, and pull firing device or a charge, batteries, electric blasting cap, and a mercury switch element.

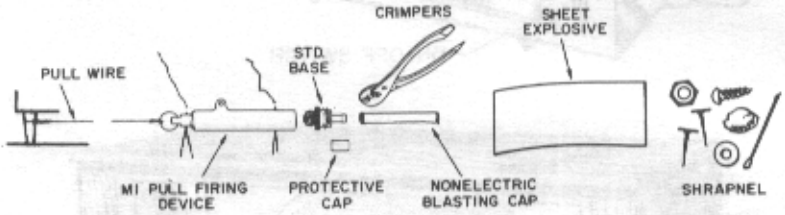
(1) *Nonelectric rigging.*

(a) Assemble pull wire, M1 pull firing device, blasting cap, and sheet explosive charge.

(b) Anchor pull wire so that a person sitting or lying on bed will initiate firing device.

(c) Conceal boobytrap.





(2) *Electric rigging.*

(a) Assemble sheet explosive charge, electric blasting cap, and mercury element.

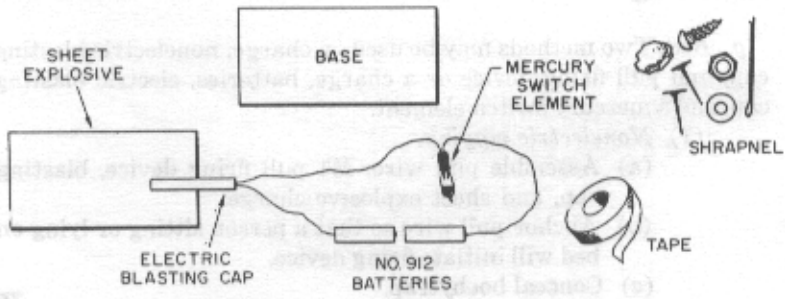
(b) Check circuit with galvanometer.

(c) Place boobytrap on bed to initiate when its level position is disturbed.

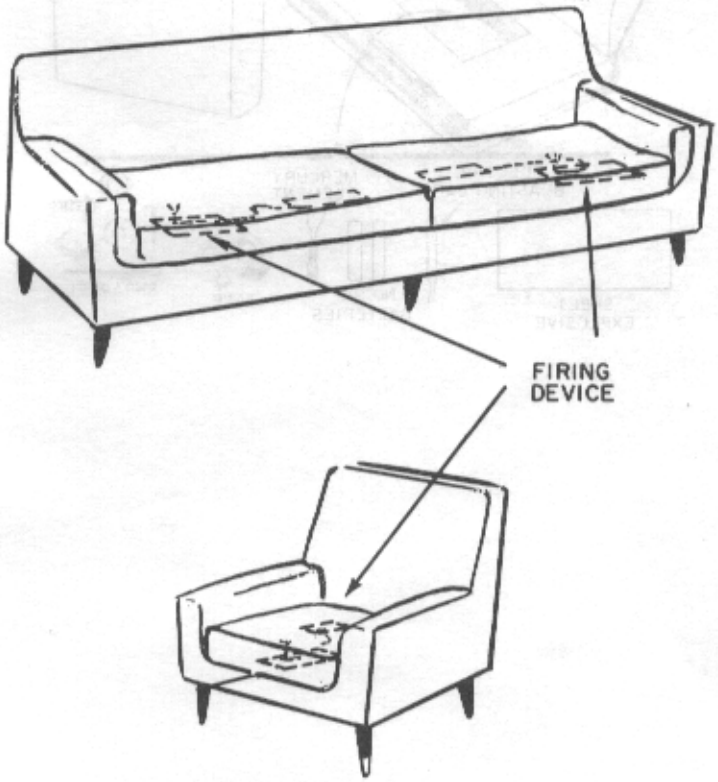
(d) Install batteries in circuit by wrapping tightly with friction tape.

(e) Conceal boobytrap.

Note. For safety and ease of assembly, use a wrist watch delay in circuit (para 60*d*).

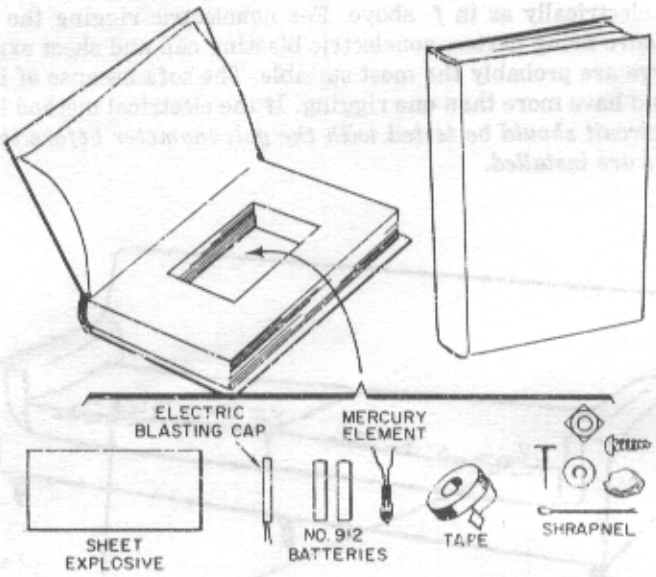


h. Chairs and Sofas. These may be boobytrapped nonelectrically and electrically as in *f* above. For nonelectric rigging the M1A1 pressure firing device, nonelectric blasting cap and sheet explosive charge are probably the most suitable. The sofa because of its size should have more than one rigging. If the electrical method is used *the circuit should be tested with the galvanometer before the batteries are installed.*



i. Book. A book with an attractive cover is sure to invite examination.

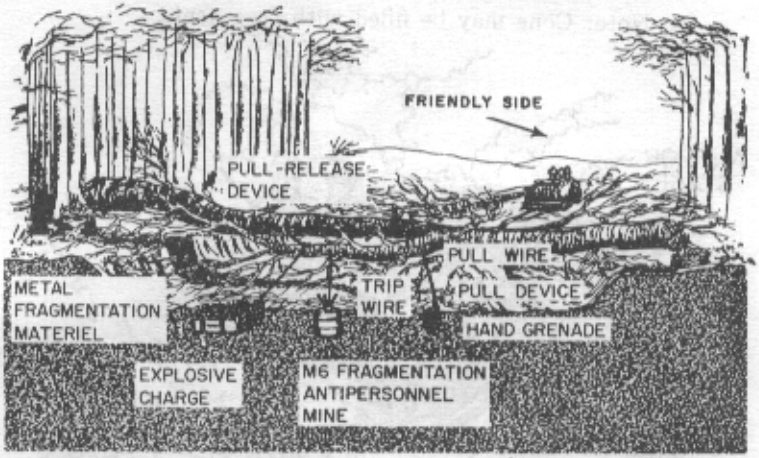
(1) Cut hole in book large enough to accommodate the rigging.
(2) Assemble sheet explosive, electric blasting cap, mercury element, and shrapnel.
(3) *Test circuit with galvanometer first,* then
(4) Secure batteries in circuit by wrapping tightly with friction tape.


ELECTRIC
BLASTING CAP
MERCURY
ELEMENT
SHEET
EXPLOSIVE
NO. 912
BATTERIES
TAPE
SHRAPNEL

Section III. TERRAIN

45. Highways, Trails, and Paths

Boobytraps used along roads are a great help in slowing down enemy traffic, especially if they are laid in and around other obstructions. Those placed on paths and trails are excellent against raiding parties that must operate under cover of darkness.



46. Locations

Boobytraps in roadway obstructions should be concealed on the enemy side. If the obstruction is heavy, requiring force to remove it, boobytraps concealed underneath will increase its effectiveness. Fragmentation charges are very destructive against personnel. These include hand grenades; bounding antipersonnel mines with their own special fuzes actuated by pressure or trip wire; ordinary explosive charges covered with pieces of scrap metal, nails, gravel, lengths of wire, nuts and bolts; and the like. The latter may be actuated by any of the standard firing devices—by pressure, pressure-release, pull-release, and pull.

a. The jet of the M2A3 shaped charge from the roadside directed into a moving vehicle is very destructive.

(1) Assemble an M3 pull-release firing device and detonator, length of detonating cord, priming adapter, and nonelectric blasting cap.

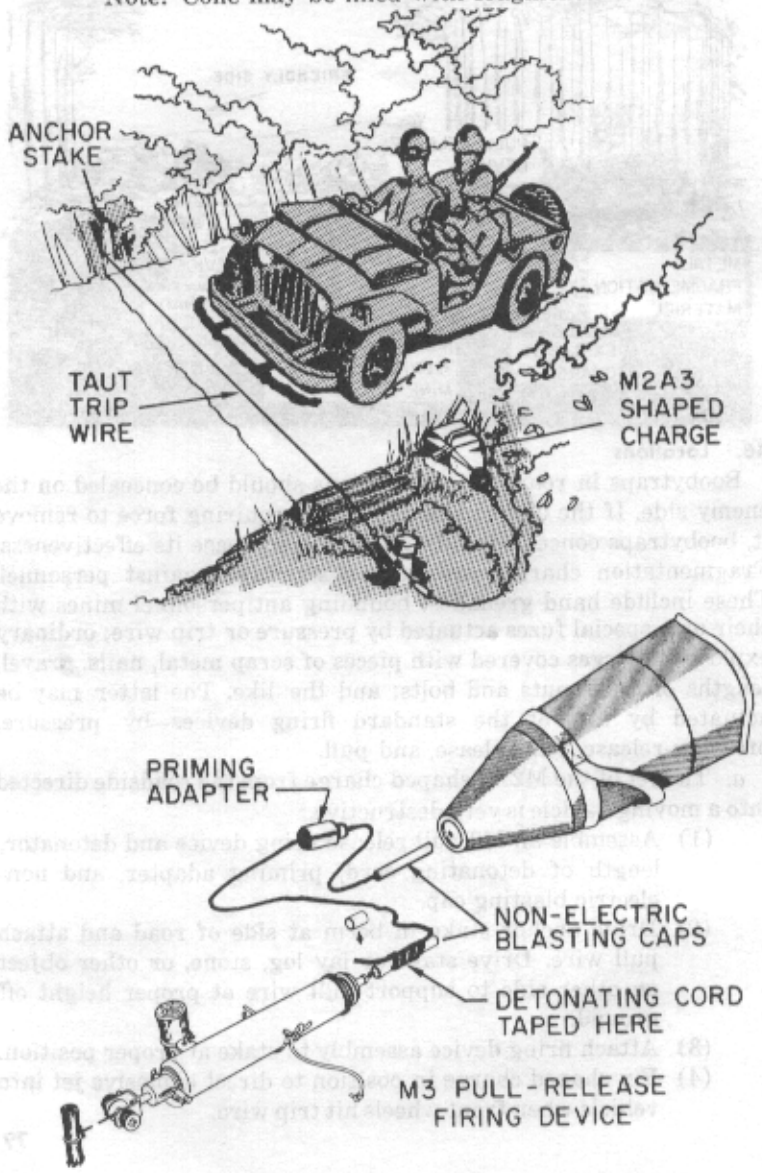
(2) Drive anchor stake in berm at side of road and attach pull wire. Drive stake or lay log, stone, or other object on other side to support pull wire at proper height off ground.

(3) Attach firing device assembly to stake at proper position.

(4) Fix shaped charge in position to direct explosive jet into vehicle when front wheels hit trip wire.

(5) Attach free end of pull wire in hole in winch and draw taut.
(6) Screw priming adapter and nonelectric blasting cap in threaded cap well.
(7) Conceal boobytrap.
(8) Arm firing device.

Note: Cone may be filled with fragments.

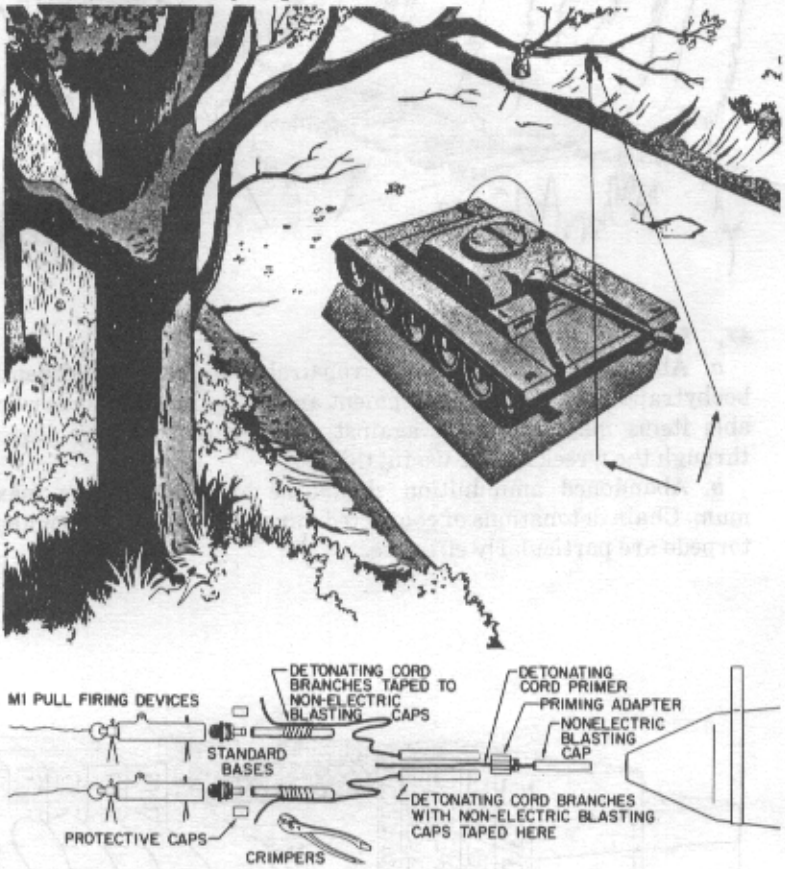


b. An M3 shaped charge boobytrap placed overhead in a tree in a wooded area will destroy both tank and crew if located properly. Trip wire, being very thin and camoufloage-colored, is not easily detected by a driver.

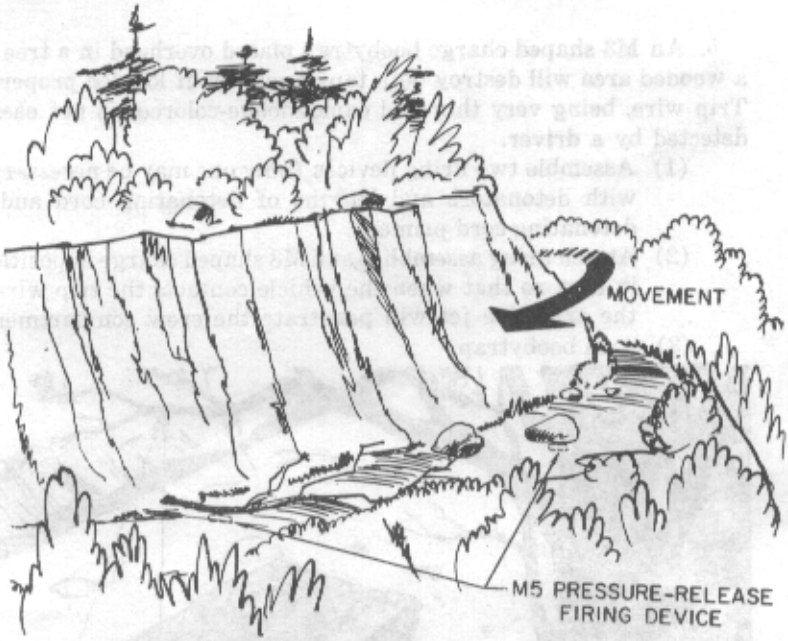
(1) Assemble two firing devices (only one may be necessary) with detonators and lengths of detonating cord and a detonating cord primer.

(2) Attach firing assemblies and M3 shaped charge in position in tree, so that when the vehicle contacts the trip wires, the explosive jet will penetrate the crew compartment.

(3) Arm boobytrap.



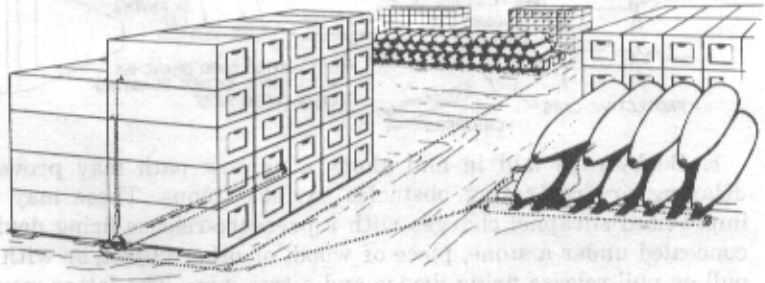
c. Boobytraps laid in and along a narrow path may prove a delaying or frustrating obstacles to foot troops. These may be improvised shrapnel charges with a pressure-release firing device concealed under a stone, piece of wood, or other object, or with a pull or pull-release firing device and a trip wire. The latter would be very effective against patrols.



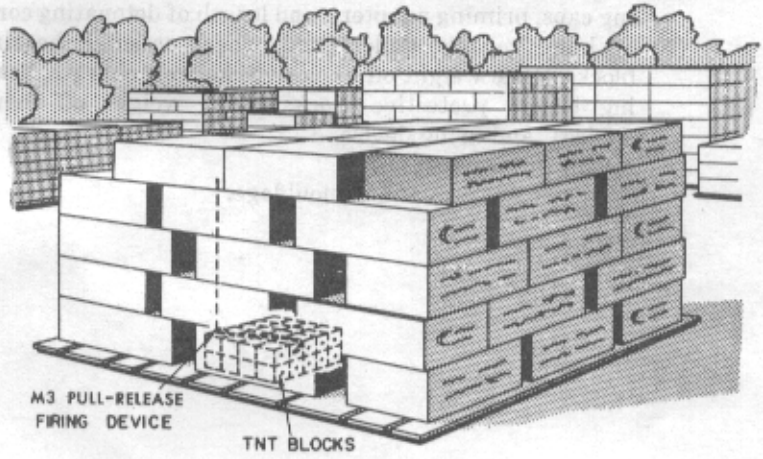
47. Special Locations

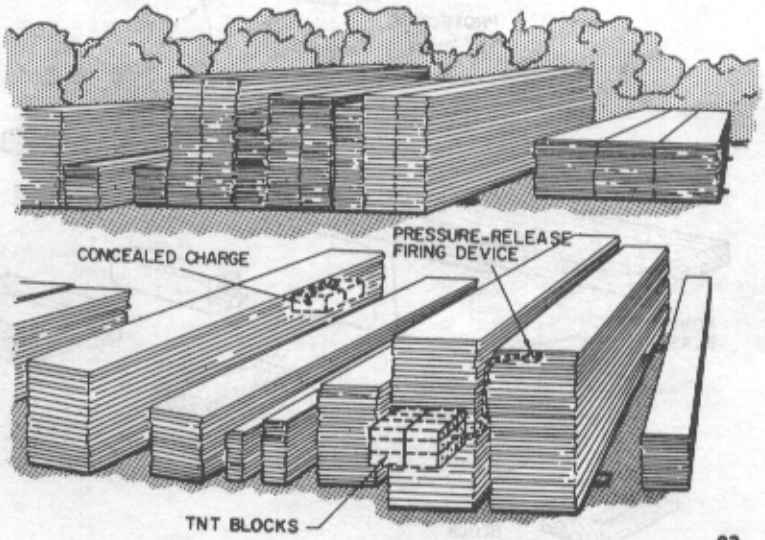
a. Abandoned serviceable or repairable items are frequently boobytrapped if time and equipment are available. Even unserviceable items may be rigged against scavangers who may search through the wreckage for useful things.

b. Abandoned ammunition should be exploited to the maximum. Chain detonations of connected mines or sections of bangalore torpedo are particularly effective.



c. Boobytraps are applicable to storage areas where materials cannot be removed or destroyed. Several charges strategically laid will prove very rewarding. A lumber pile provides excellent concealment for an explosive rigging. Sheet explosive may be used in many places where TNT is impractical, because of its size and shape. Here again chain detonations of explosive blocks and bangalore torpedos will do extensive damage, if the firing mechanism is properly located and cunningly concealed.





48. Abandoned Vehicles

a. Truck Wheel.

(1) Insert length of heavy wire in interceptor hole in firing device.

(2) Remove safety pin and replace with length of thin wire. Bend both wires slightly to prevent falling out.

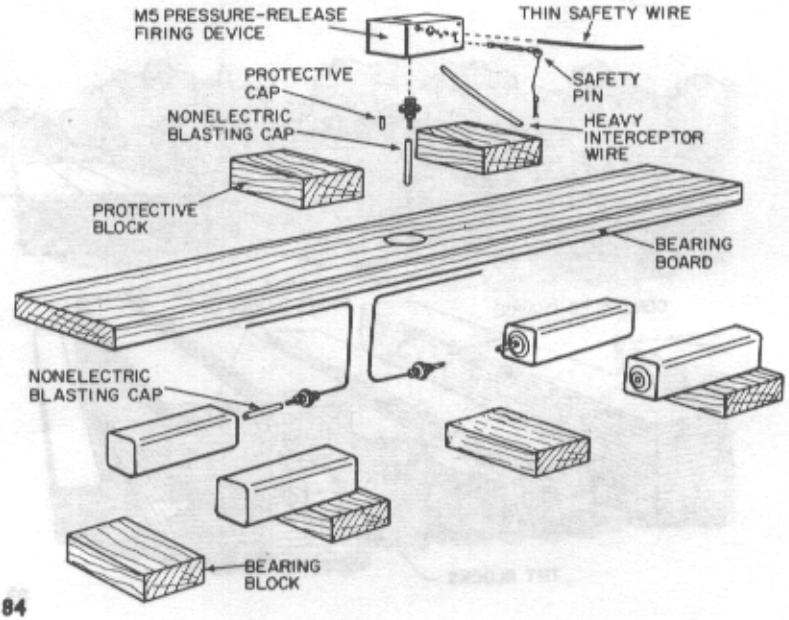
(3) Assemble standard base, nonelectric blasting cap, and firing device.

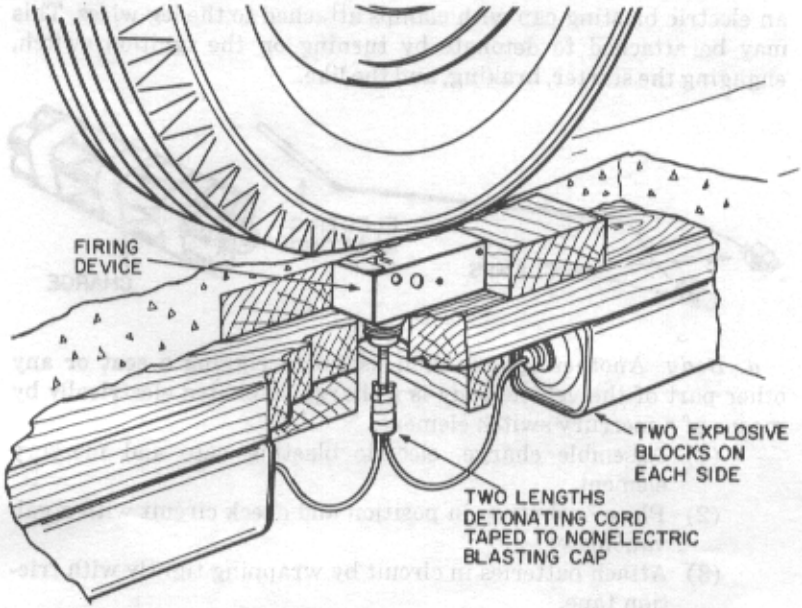
(4) Assemble two 2-block explosive charges, nonelectric blasting caps, priming adapters, and length of detonating cord.

(5) In hole prepared under truck wheel, assemble bearing blocks (take weight off explosive charge), charges, bearing board, protective blocks (take weight off firing device), and firing device.

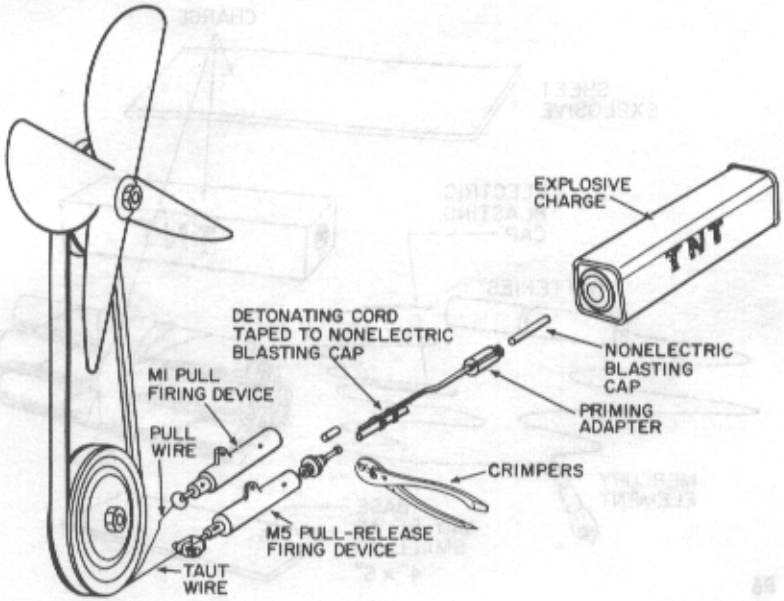
(6) Arm firing device.

(7) Cover boobytrap, and camoulflage.

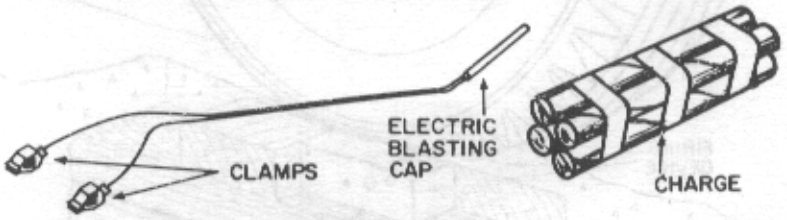




b. Motor. The fan belt is an excellent anchor for a pull wire. The pull wire will be much harder to detect if anchored underneath the bottom pulley, from where it may be extended any length to the firing device and charge.



c. Electric System. A useful combination is a charge primed with an electric blasting cap with clamps attached to the leg wires. This may be attached to detonate by turning on the ignition switch, engaging the starter, braking, and the like.



d. Body. Another combination useful in rigging a seat or any other part of the vehicle body is a charge detonated electrically by means of a mercury switch element.

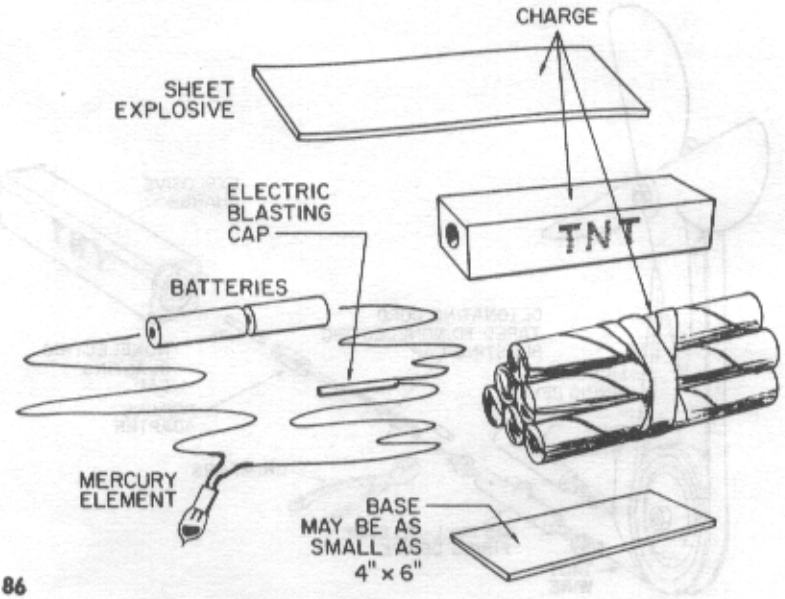
(1) Assemble charge, electric blasting cap, and mercury element.

(2) Place boobytrap in position and check circuit with a galvanometer.

(3) Attach batteries in circuit by wrapping tightly with friction tape.

Note. Always check circuit before attaching batteries.

This rigging may be assembled in a small package for use in a seat cushion or separated for convenience for another location in the body of the vehicle.



CHAPTER 5

MISCELLANEOUS BOOBYTRAPS

Section I. STANDARD BOOBYTRAPS

49. Tactical Use

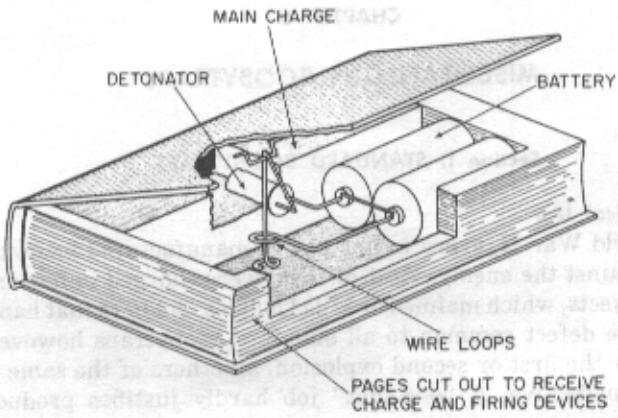
In World War II, every major power manufactured boobytraps to use against the enemy. Most of them were charged imitations of useful objects, which maimed or killed helpless soldiers that handled them. The defect common to all standard boobytraps however, is that after the first or second explosion, all others of the same type become ineffective. A "one-shot" job hardly justifies production costs.

50. Foreign Types

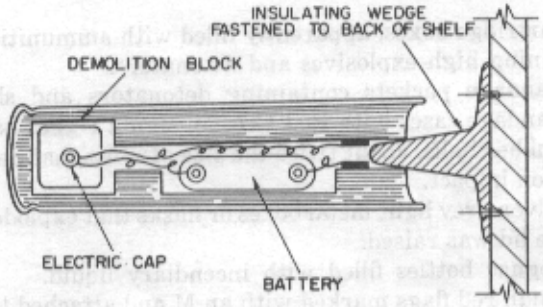
a. The Soviets used more standard boobytraps in World War II than any other combatant. A weird assortment of charged imitations of items issued to German soldiers were dropped from Soviet planes. Some of these were:

(1) Cartridge boxes, apparently filled with ammunition, containing high explosives and detonators.
(2) Bandage packets containing detonators and shrapnel.
(3) Bandage cases with Red Cross insignia rigged as mines.
(4) Rubber balls, about twice the size of a fist that detonated upon impact.
(5) Silver-grey light metal boxes or flasks that exploded when the lid was raised.
(6) Cognac bottles filled with incendiary liquid.
(7) Small red flags marked with an M and attached to mines that detonated when the flag was removed.
(8) Imitation earth-grey colored frogs that detonated when pressed on.
(9) Flashlights containing high explosive which detonated when the switch was moved.
(10) Mechanical pencils, watches, cigarette cases, cigarette lighters, salt cellars, and similar items that detonated when handled.

b. Knowing the German interest in books, the Soviets prepared a book boobytrap. The charge inside detonated when the cover was raised.

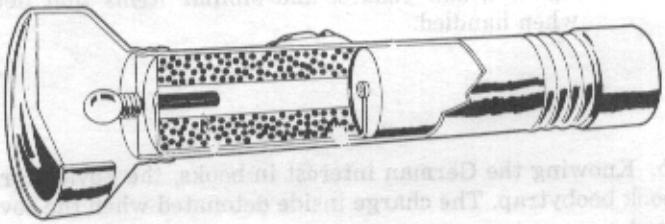


c. The British also had a book boobytrap; but it was slightly more complicated than the Soviet version, above.



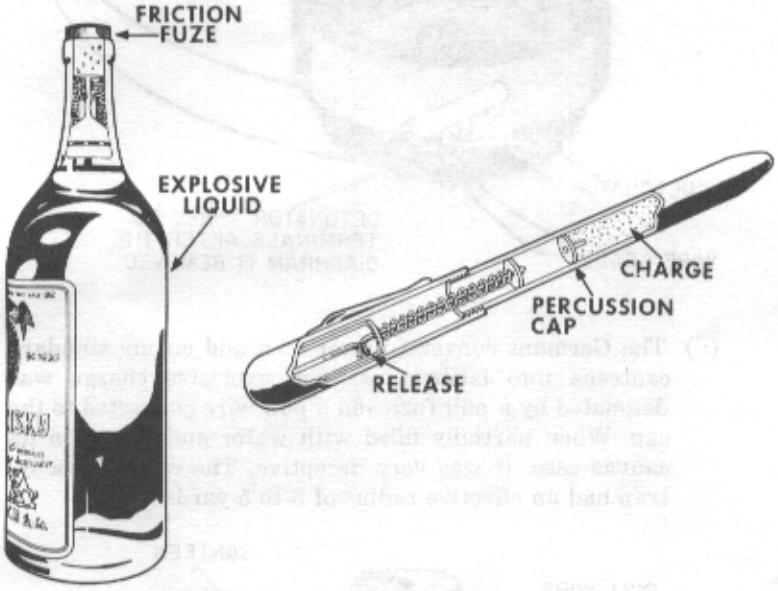
d. All sorts of dirty-trick devices were used by the enemy.

(1) A flashlight was rigged with a charge and an electric detonator powered and actuated by the original dry cell battery switch, and circuit.

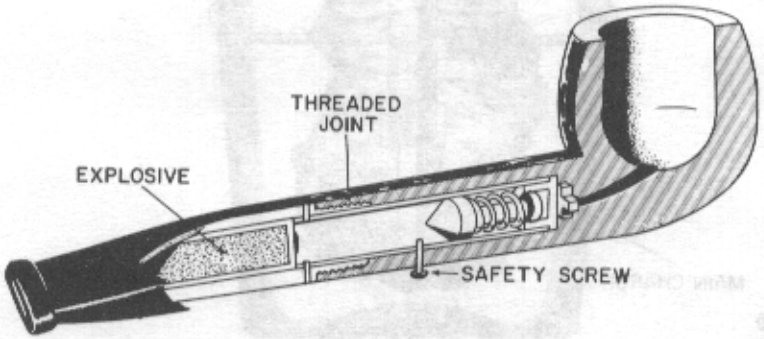


(2) Bottles designed to look like liquor bottles were filled with a liquid explosive detonated by a pull-friction fuze attached to the cork.

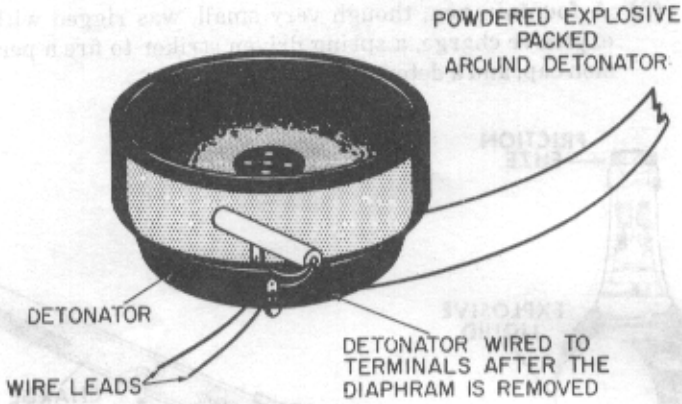
(3) A fountain pen, though very small, was rigged with an explosive charge, a spring driven striker to fire a percussion cap, and a detonator.



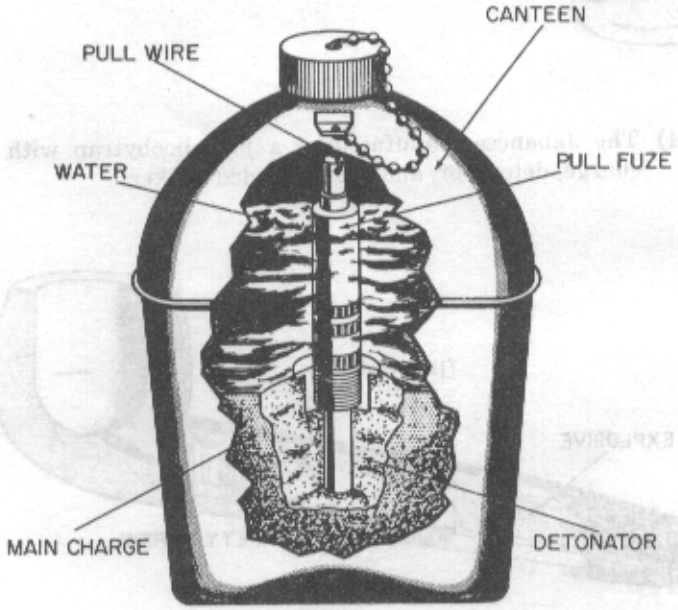
(4) The Japanese manufactured a pipe boobytrap with a charge, detonator, and spring-loaded striker.



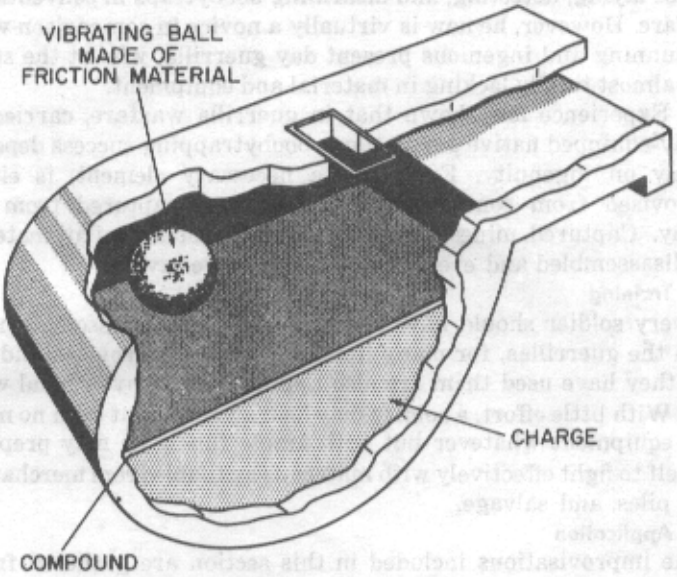
(5) The Italians had a boobytrapped headset containing an electric detonator connected to the terminals on the back. The connection of the headset into the live communication line initiated detonation.


POWDERED EXPLOSIVE PACKED AROUND DETONATOR
DETONATOR
WIRE LEADS
DETONATOR WIRED TO TERMINALS AFTER THE DIAPHRAM IS REMOVED

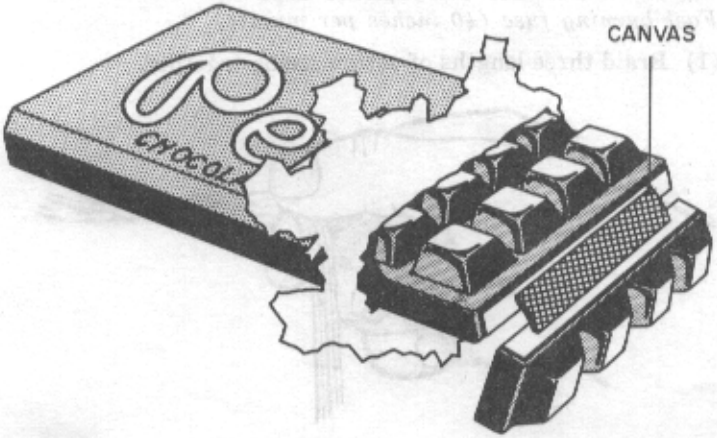
(6) The Germans converted their own and enemy standard canteens into boobytraps. The explosive charge was detonated by a pull fuze and a pull wire connected to the cap. When partially filled with water and placed in its canvas case, it was very deceptive. The canteen boobytrap had an effective radius of 3 to 5 yards.



(7) Another German device was the boobytrap whistle. This consisted of a policeman's or referee's whistle with a charge and a metal ball covered with a layer of friction compound. Blowing the whistle moved the ball, igniting the friction compound and detonating the charge.



(8) The German Peters candy bar boobytrap was ingenious indeed. The explosive charge, fuze, and thin canvas pull device were covered with chocolate.



51. Ingenuity

a. Through information on military operations in World War II, the U.S. soldier has been well-prepared for the dangerous mission of laying, detecting, and disarming boobytraps in conventional warfare. However, he now is virtually a novice in comparison with the cunning and ingenious present day guerrilla, who at the start was almost totally lacking in material and equipment.

b. Experience has shown that in guerrilla warfare, carried on by illy-equipped native populations, boobytrapping success depends largely on ingenuity. Explosive, a necessary element, is either improvised from commercial ingredients or captured from the enemy. Captured mines, ammunition, and other similar material are disassembled and every ounce of explosive saved.

52. Training

Every soldier should have some training in the lessons learned from the guerrillas, for many items they have improvised and the way they have used them are also applicable to conventional warfare. With little effort, a soldier may be trained so that with no military equipment whatever but with ample funds, he may prepare himself to fight effectively with materials available from merchants, junk piles, and salvage.

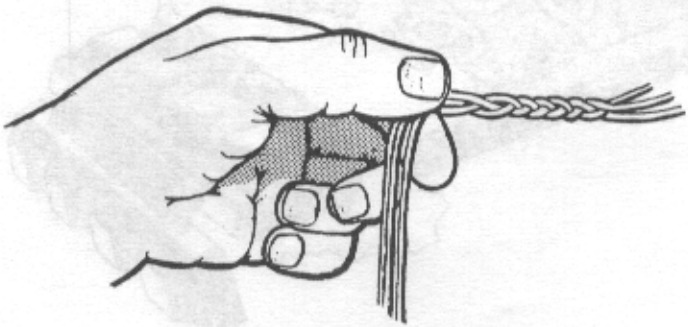
53. Application

The improvisations included in this section are gathered from numerous sources. Some may have wider application to boobytrapping than others. How the guerrilla may use them, however, is unpredictable. All are presented to stimulate initiative and arouse enthusiasm to out-do backward enemy peoples in devising and placing boobytraps and to develop a higher level of proficiency than ever before in their detection and removal.

54. Improvised Time Fuze and Explosive Caps

a. Fast burning fuse (40 inches per minute).

(1) Braid three lengths of cotton string together.



(2) Moisten fine black powder to form a paste. Rub paste into twisted string with fingers and allow to dry. If a powder is not available, mix 25 parts potassium nitrate (saltpeter) in an equal amount of water and add 3 parts pulverized charcoal and 2 parts pulverized sulphur to form a paste. Rub paste into twisted string and allow to dry.

(3) Check burning rate before using.

b. Slow burning fuse (2 inches per minute).

(1) Wash three lengths of string or three shoelaces in hot soapy water and rinse.

(2) Dissolve 1 part potassium nitrate or potassium chlorate and 1 part granulated sugar in 2 parts hot water.

(3) Soak string or shoelaces in solution and braid three strands together. Allow to dry.

(4) Check burning rate.

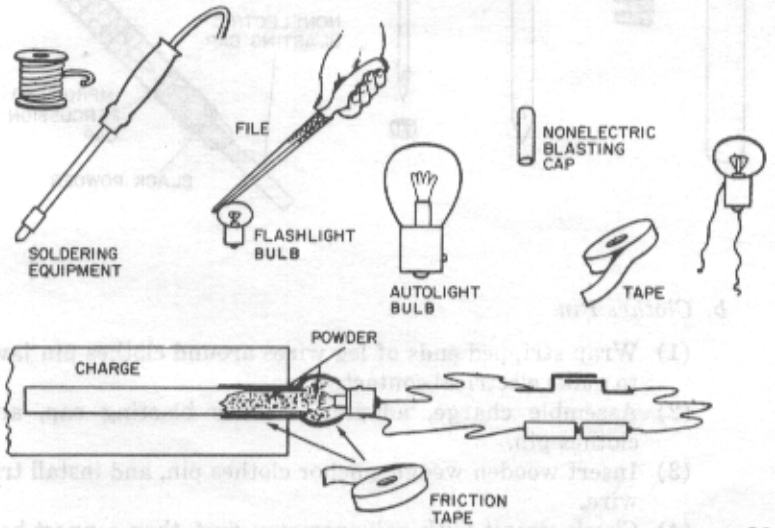
(5) Before using, coat several inches of the end to be inserted into cap or material to be ignited with black powder paste (*a* (2) above).

c. Electric Blasting Cap.

(1) With file or other instrument make hole in end of light bulb.

(2) If jacket is not available, solder or securely fasten two wires to bulb—one on metal threads at side and other at metal contact on bottom.

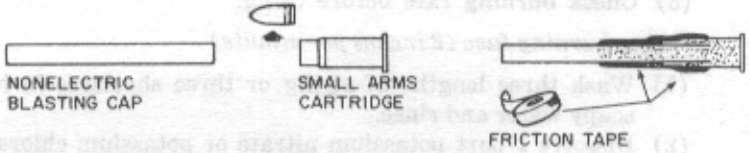
(3) Fill bulb and empty portion of blasting cap with black powder. Tape blasting cap on top of bulb.



d. Percussion Cap Assembly.

(1) Remove projectile, but not powder, from small arms cartridge.

(2) Tape nonelectric blasting cap securely in cartridge.

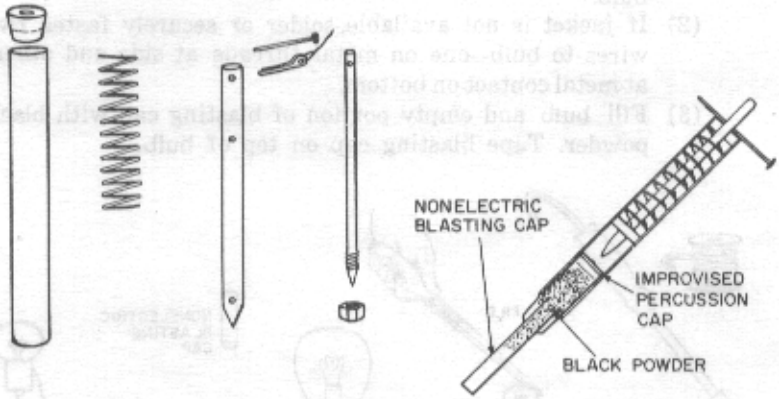


55. Pull Firing Devices

a. Tube and Striker.

Assemble tube, spring, striker shaft with hole or with hex nut, soft wood or metal top plug, pull pin, and improvised percussion cap assembly.

Note. Always assemble firing device before attaching the improvised percussion cap assembly.



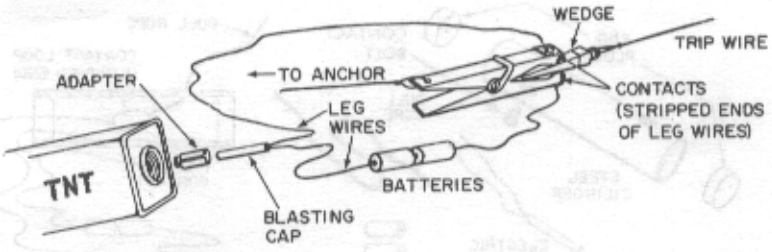
b. Clothes Pin.

(1) Wrap stripped ends of leg wires around clothes pin jaws to make electrical contact.

(2) Assemble charge, adapter, electric blasting cap, and clothes pin.

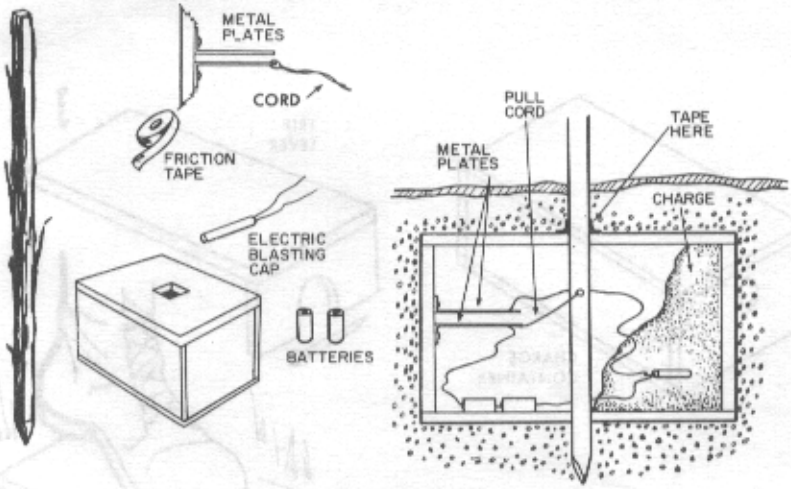
(3) Insert wooden wedge, anchor clothes pin, and install trip wire.

(4) Check circuit with galvonometer *first*, then connect batteries.



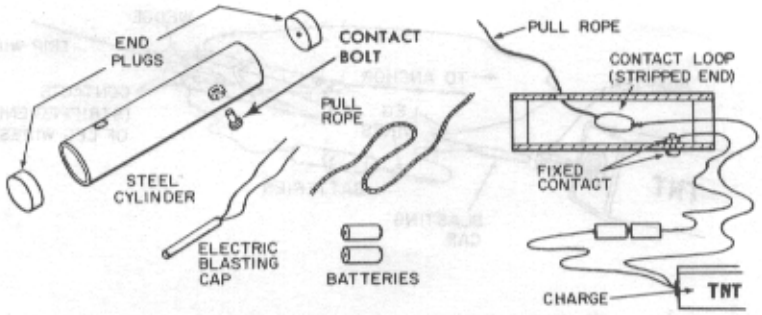
c. Stake or Pole Initiator.

(1) Assemble stake or pole, container, metal contact plates, charge, electric blasting cap, and pull cord.
(2) Check circuit with galvonometer *first*, then connect batteries.
(3) Fasten down top of container and seal hole around stake with friction tape.



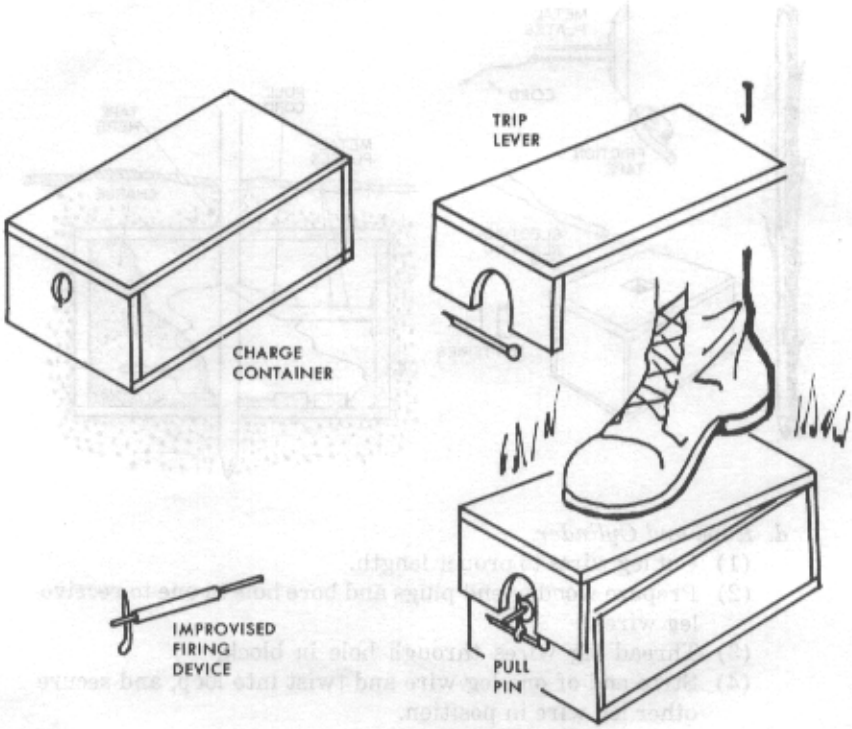
d. Rope and Cylinder.

(1) Cut leg wires to proper length.
(2) Prepare wooden end plugs and bore hole in one to receive leg wires.
(3) Thread leg wires through hole in block.
(4) Strip end of one leg wire and twist into loop, and secure other leg wire in position.
(5) Test circuit with galvonometer.
(6) Assemble metal cylinder, contact bolt, pull cord, charge, blasting cap, end blocks, and batteries.

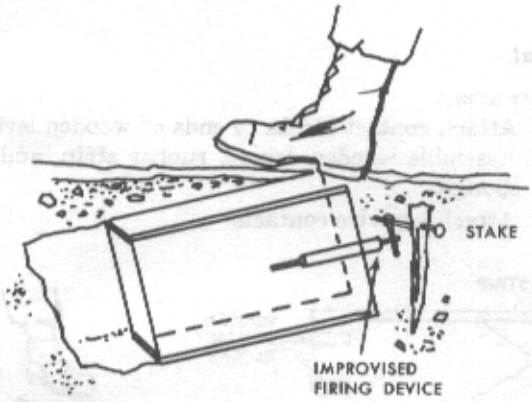


e. Trip Lever and Pull Pin.

(1) *Flat placement.*
Assemble container, charge, improvised pull firing device (*a* above) and trip lever.



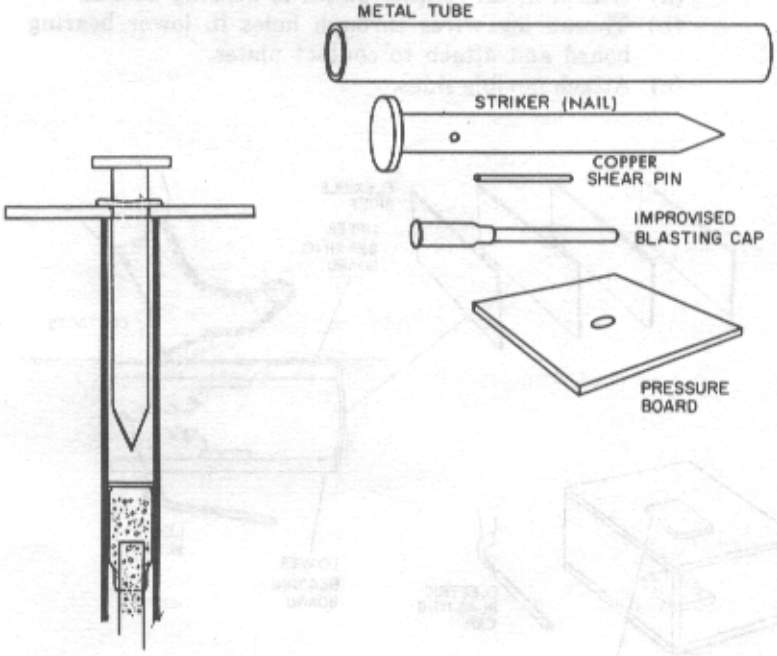
(2) *Sloping placement.*
Assemble container, charge, improvised firing device (*a* above) and stake.



56. Pressure Firing Devices

a. Mechanical Concussion.

(1) Force striker into hole in pressure board.
(2) Insert wood or soft metal shear pin in shear pin hole.
(3) Assemble striker, metal tube, and improvised blasting cap (para 54).



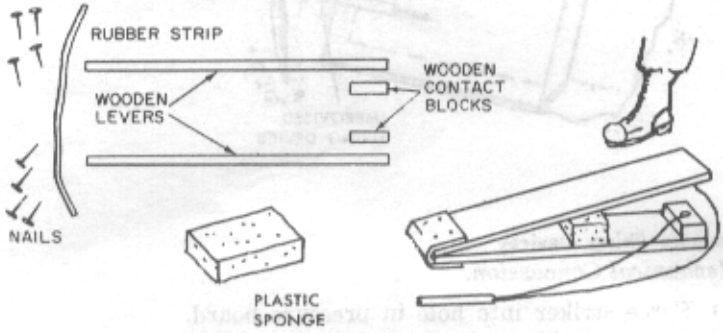
b. *Electrical.*

(1) *Lever arm.*

(a) Attach contact blocks to ends of wooden levers.

(b) Assemble wooden levers, rubber strip, and plastic sponge.

(c) Attach leg wire contacts.

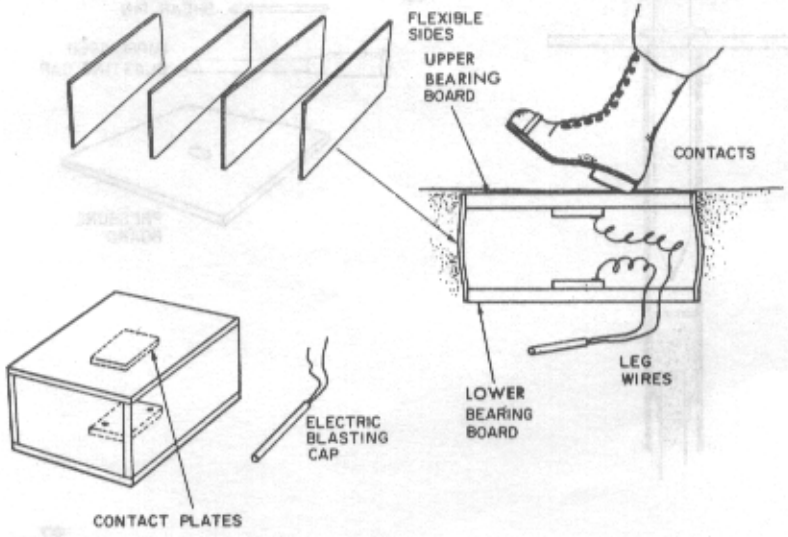


(2) *Flexible side.*

(a) Attach metal contact plates to bearing boards.

(b) Thread leg wires through holes in lower bearing board and attach to contact plates.

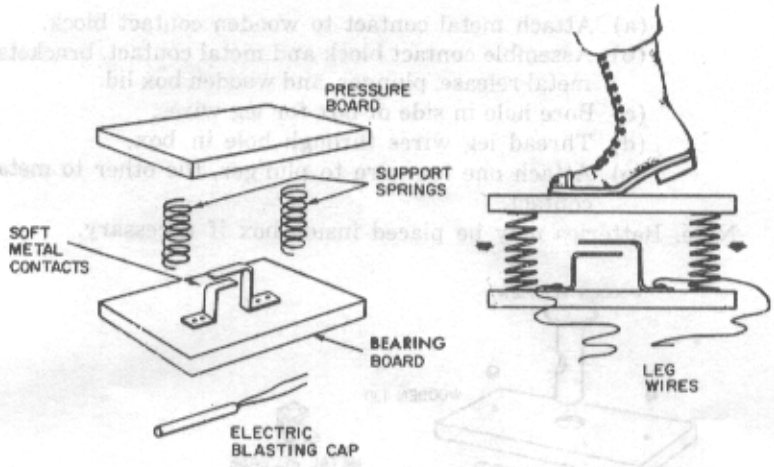
(c) Attach flexible sides.

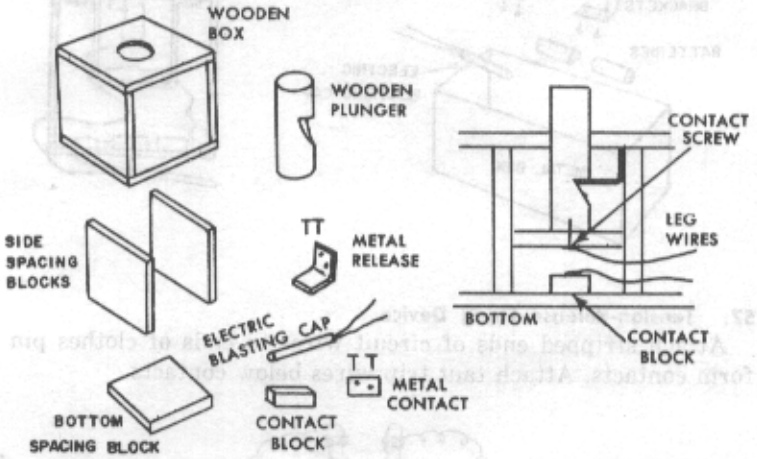


(3) *Springed pressure board.*

(a) Assemble metal contacts, springs, bearing board, and pressure board.

(b) Attach leg wires to metal contacts.





(4) *Wooden plunger.*

(a) Assemble box, leaving one side open.

(b) Assemble contact plate and three spacing blocks inside box.

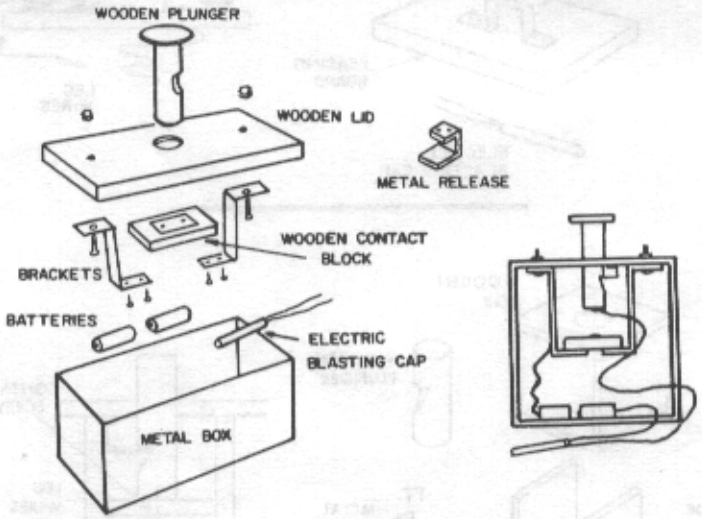
(c) Drill holes in spacing block for leg wires.

(d) Assemble plunger, metal release, contact block, metal contact, and contact screw.
(e) Thread leg wire through holes in spacing block and attach to contacts.

(5) *Metal box.*

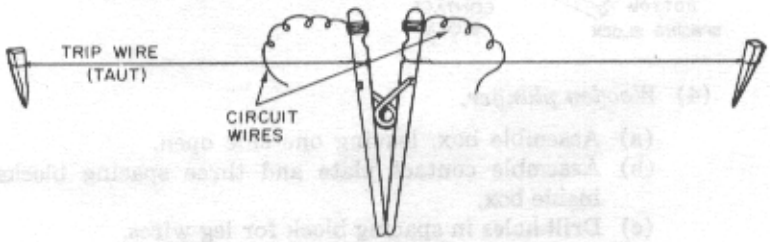
(a) Attach metal contact to wooden contact block.
(b) Assemble contact block and metal contact, brackets, metal release, plunger, and wooden box lid.
(c) Bore hole in side of box for leg wires.
(d) Thread leg wires through hole in box.
(e) Attach one leg wire to plunger, the other to metal contact.

Note. Batteries may be placed inside box if necessary.



57. Tension-Release Firing Device

Attach stripped ends of circuit wires to ends of clothes pin to form contacts. Attach taut trip wires below contacts.



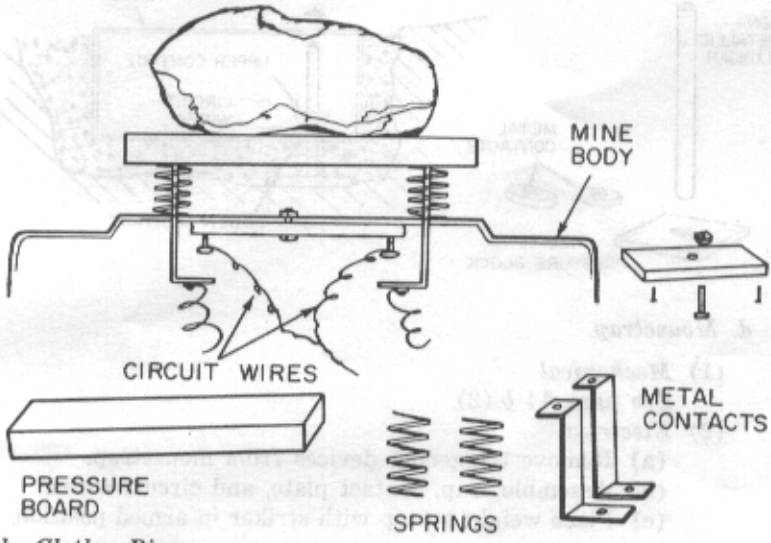
58. Pressure-Release

a. Double Contact.

(1) Bore holes in top of mine body to accommodate long contacts.

(2) Assemble pressure board, coil springs, wooden contact board and metal contacts.

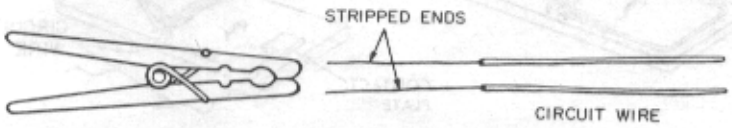
(3) Attach circuit wires.

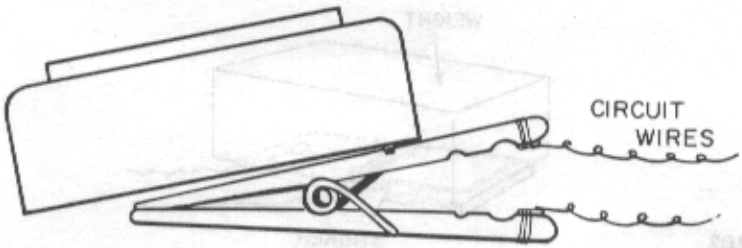


b. Clothes Pin.

(1) Attach stripped ends of circuit wires to clothes pin to make contacts.

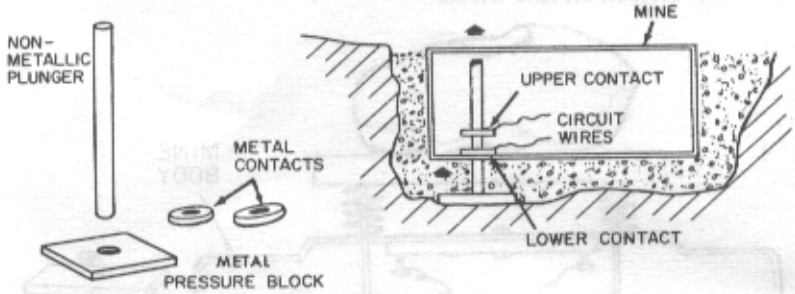
(2) Place mine on top, keeping contacts apart.





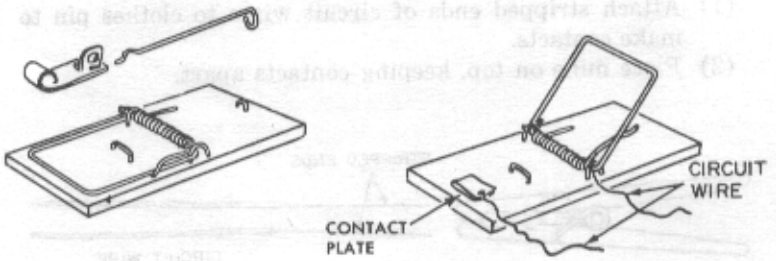
c. Bottom Plunger.

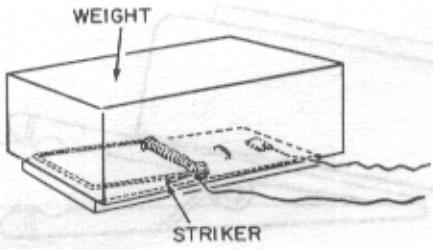
(1) Bore hole in bottom of mine case to admit plunger.
(2) Attach lower metal contact over hole.
(3) Assemble mine, pressure block, upper metal contact, and nonmetallic plunger.
(4) Attach circuit wires.



d. Mousetrap.

(1) *Mechanical*
See para 44 *b* (2)
(2) *Electrical*
(a) Remove triggering devices from mousetrap.
(b) Assemble trap, contact plate, and circuit wires.
(c) Place weight on top with striker in armed position.

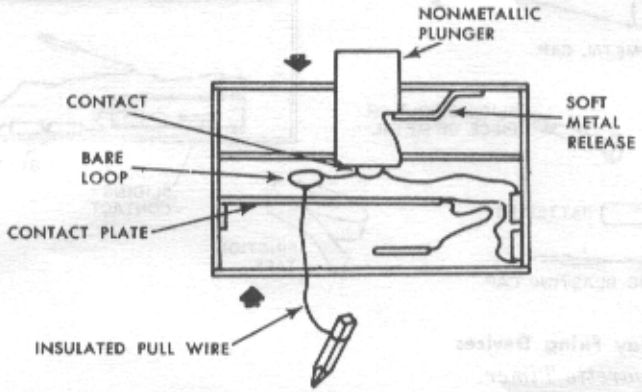




59. Anti-Lift Devices

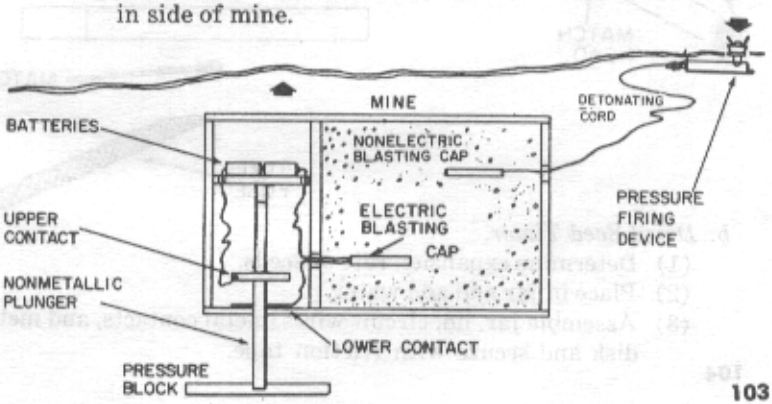
a. Loop Contact.

(1) Drill hole in bottom of mine to admit insulated pull wire.
(2) Assemble plunger, metal release, and contact plate.
(3) Attach circuit wires and bare loop to plunger contact and contact plate.
(4) Thread anchored insulated trip wire through holes in bottom of mine and contact plate and attach to bare loop.



b. Double Detonator.

(1) Drill three holes—one in bottom, one in partition, and one in side—to admit nonmetallic plunger and two electric blasting caps.
(2) Assemble blasting cap, leg wires, contact plates, plunger and pressure block.
(3) *Check circuit with galvonometer first.* Then connect batteries with friction tape.
(4) Install blasting cap connected to pressure firing device in side of mine.

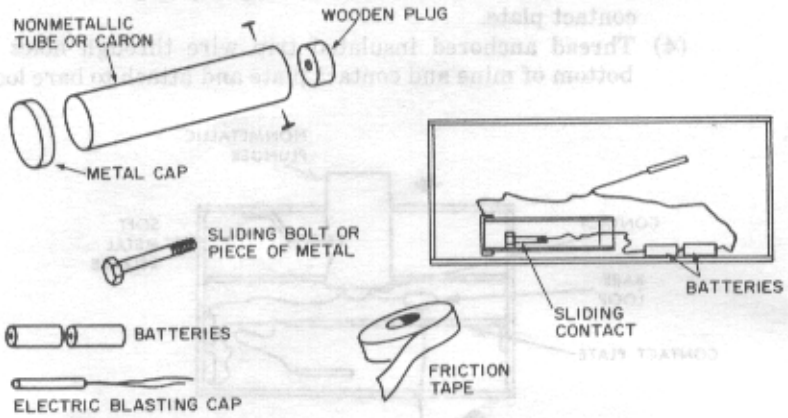


c. Sliding Contact.

(1) Assemble metal cap, nonmetallic tube or carton, sliding contact, wooden plug, and leg wires at contacts.

(2) *Check circuit with a galvonometer first,* then connect batteries with friction tape.

(3) Install assembly in tube.



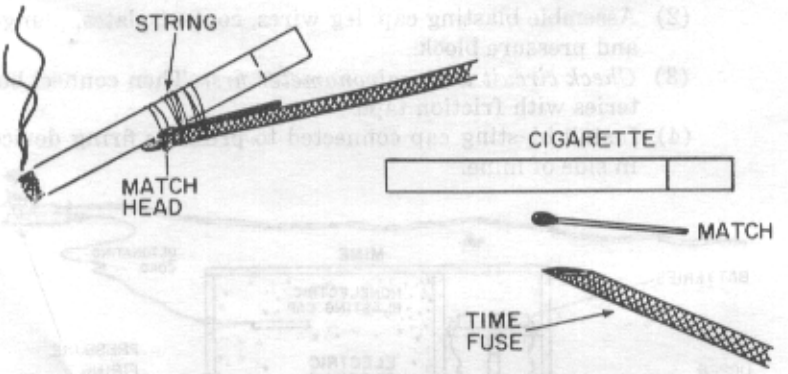
60. Delay Firing Devices

a. Cigarette Timer.

(1) Test burning rate of time fuze and cigarette. (A cigarette usually burns at the rate of 1 inch in 7 to 8 minutes.)

(2) Cut sloping end on length of time fuze.

(3) Assemble sloped end of time fuze, match head, and cigarette.

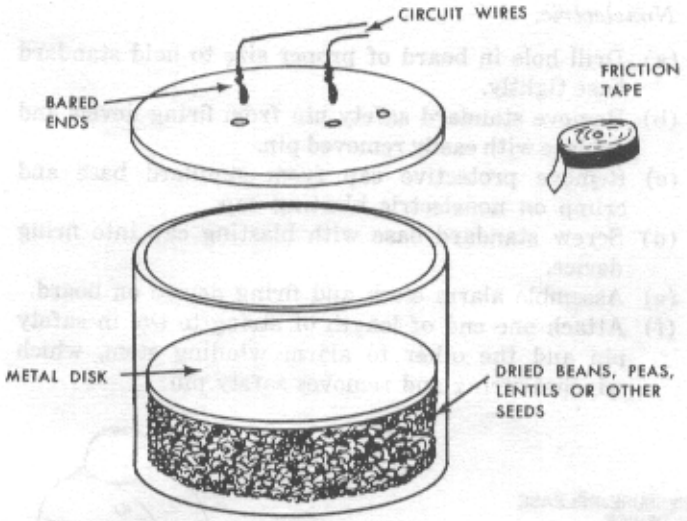


b. Dried Seed Timer.

(1) Determine expansion rate of seeds.

(2) Place in jar and add water.

(3) Assemble jar, lid, circuit wires, metal contacts, and metal disk and secure with friction tape.



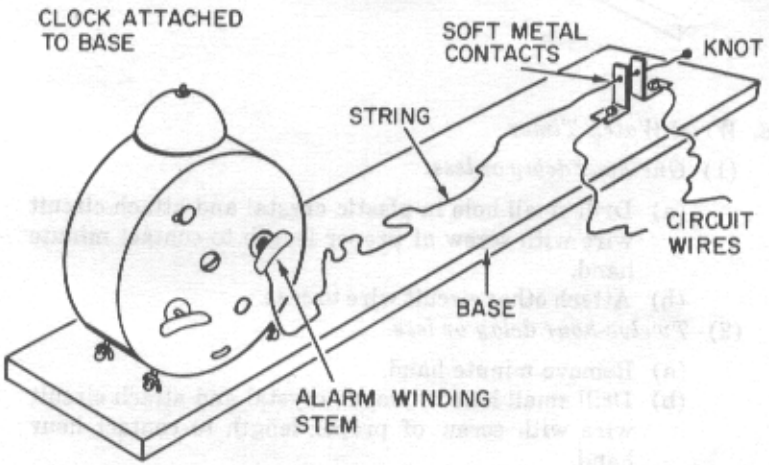
c. Alarm Clock Timers.

(1) *Electric.*

(a) Assemble base, metal contacts, and alarm clock.

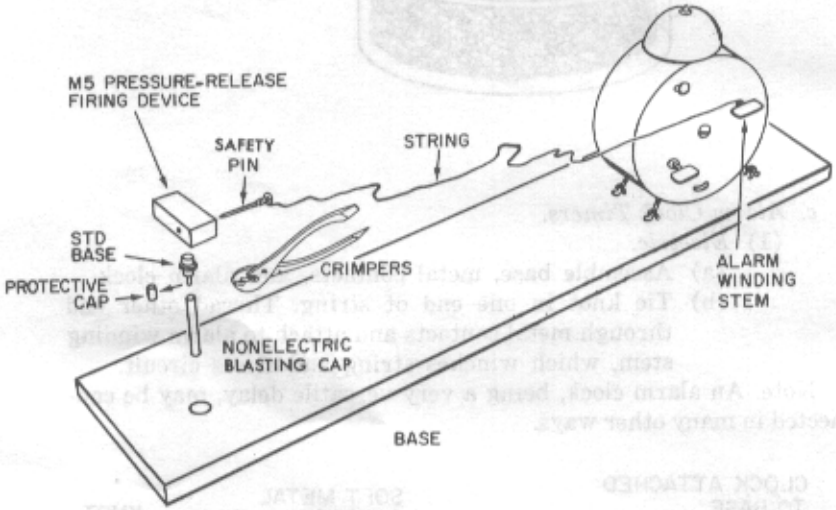
(b) Tie knot in one end of string. Thread other end through metal contacts and attach to alarm winding stem, which winches string and closes circuit.

Note. An alarm clock, being a very versatile delay, may be connected in many other ways.



(2) *Nonelectric.*

(a) Drill hole in board of proper size to hold standard base tightly.
(b) Remove standard safety pin from firing device and replace with easily removed pin.
(c) Remove protective cap from standard base and crimp on nonelectric blasting cap.
(d) Screw standard base with blasting cap into firing device.
(e) Assemble alarm clock and firing device on board.
(f) Attach one end of length of string to eye in safety pin and the other to alarm winding stem, which winches string and removes safety pin.



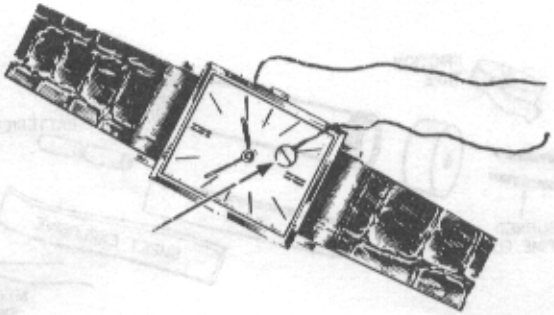
d. Wrist Watch Timer.

(1) *One-hour delay or less.*

(a) Drill small hole in plastic crystal and attach circuit wire with screw of proper length to contact minute hand.
(b) Attach other circuit wire to case.

(2) *Twelve-hour delay or less.*

(a) Remove minute hand.
(b) Drill small hole in plastic crystal and attach circuit wire with screw of proper length to contact hour hand.
(c) Attach other circuit wire to case.



61. Bombs

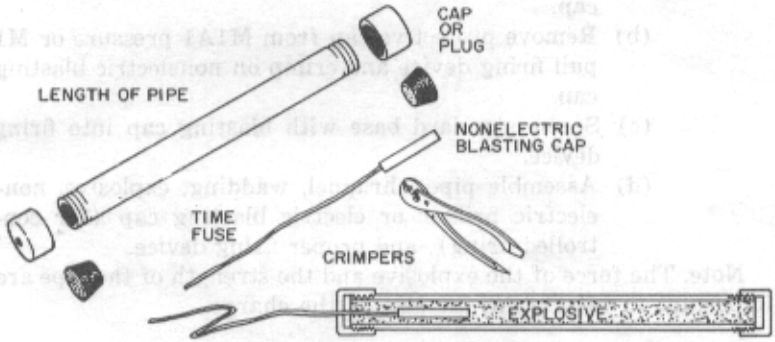
a. Pipe Bombs.

(1) *Grenade.*

(a) Drill hole in cap or plug to admit length of time fuze.

(b) Crimp nonelectric blasting cap to length of time fuze.

(c) Assemble pipe, caps or plugs, time fuze primer, and explosive charge.



(2) *Antidisturbance bomb.*

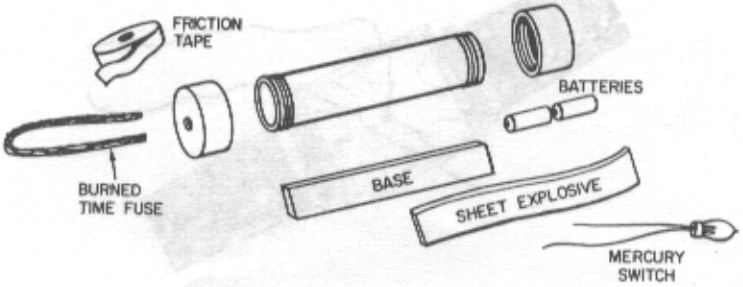
(a) Drill hole in end cap to admit length of burnt time fuze to make a bomb look like a "dud."

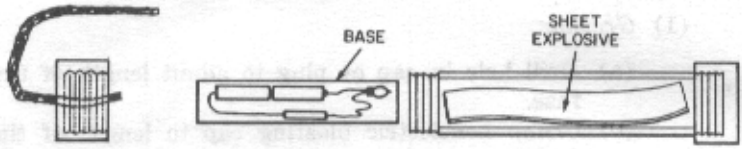
(b) Attach electric cap and mercury element on base.

(c) Test circuit with galvonometer *first*, then connect batteries with friction tape.

(d) Assemble bomb.

Caution: If possible, assemble bomb *in place*, as the mercury element, when disturbed, may cause premature explosion. To assemble more safely and easily, attach wrist watch timer in circuit.





(3) *Shotgun bomb.*

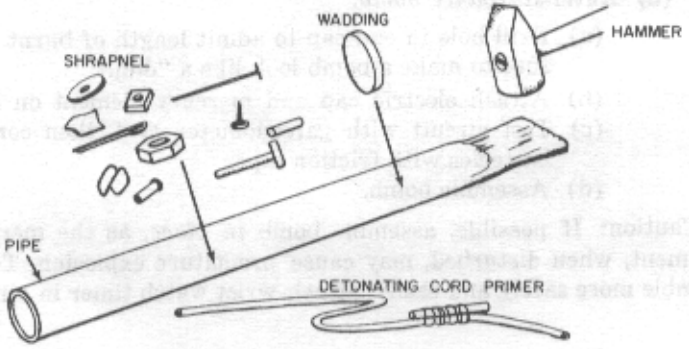
(a) Close one end of pipe with hammer, allowing opening for detonating cord primer or electric blasting cap.

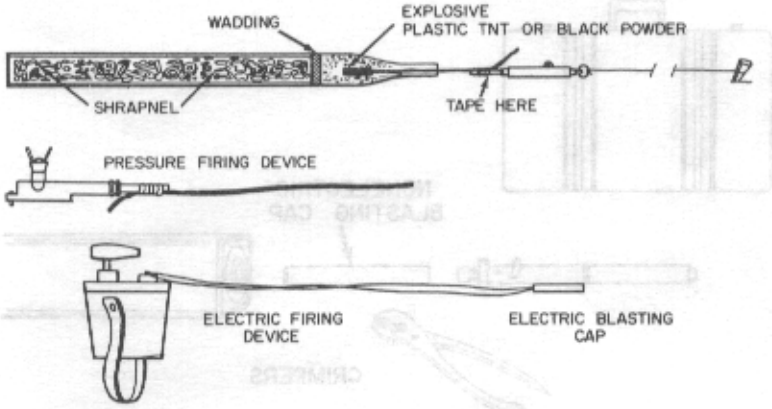
(b) Remove protective cap from M1A1 pressure or M1 pull firing device and crimp on nonelectric blasting cap.

(c) Screw standard base with blasting cap into firing device.

(d) Assemble pipe, shrapnel, wadding, explosive, nonelectric primer or electric blasting cap (for controlled firing), and proper firing device.

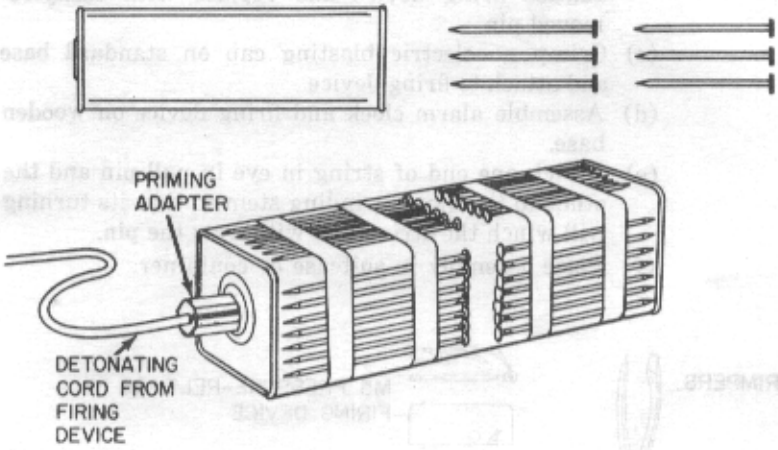
Note. The force of the explosive and the strength of the pipe are important in calculating the size of the charge.





b. Nail Grenade.

Attach nails to top and sides of charge by means of tape or string. Under certain conditions, nails may be required on only two sides, or even on one side.



c. Delay Bomb.

(1) *Chemical delay.*

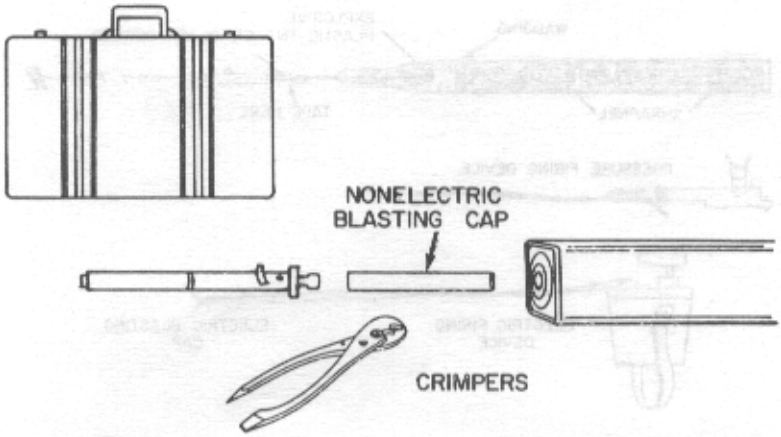
(a) Crimp nonelectric blasting cap on base of appropriate M1 delay firing device.

(b) Assemble firing device and charge in package.

(c) Crush copper end of firing device with fingers.

(d) Place package in suitcase or container.

Note. Use this bomb only when delay is necessary but accuracy is secondary, as the delay time of any chemical firing device varies considerably according to temperature.



(2) *Alarm clock delay.*

(a) Drill hole in wooden base of proper size to hold standard base firmly.

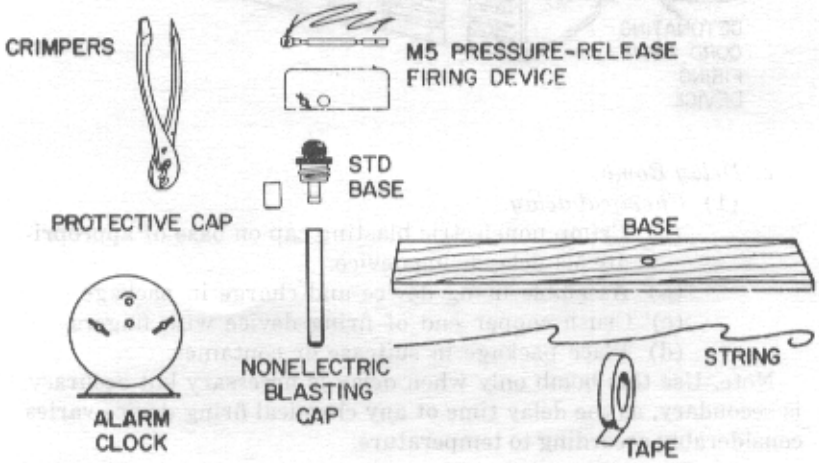
(b) Remove standard safety pin from M5 pressure-release firing device and replace with easily-removed pin.

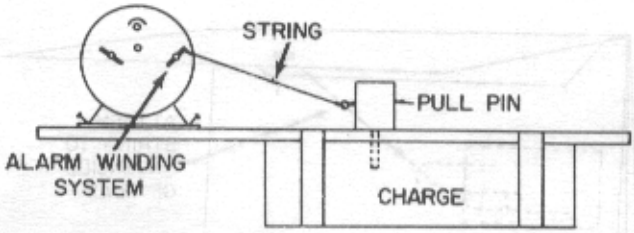
(c) Crimp nonelectric blasting cap on standard base and attach to firing device.

(d) Assemble alarm clock and firing device on wooden base.

(e) Attach one end of string in eye in pull pin and the other to the alarm winding stem so that its turning will winch the string and withdraw the pin.

(f) Place assembly in suitcase or container.





d. Envelope Bomb.

(1) Cut leg wires of electric blasting cap of proper length to make circuit.

(2) Strip insulation off ends of circuit wires and twist into ¼-inch loops to make loop switch.

(3) Test circuit with galvonometer *first*, then attach batteries.

(4) Assemble cardboard base, batteries, electric blasting cap, and explosive as package.

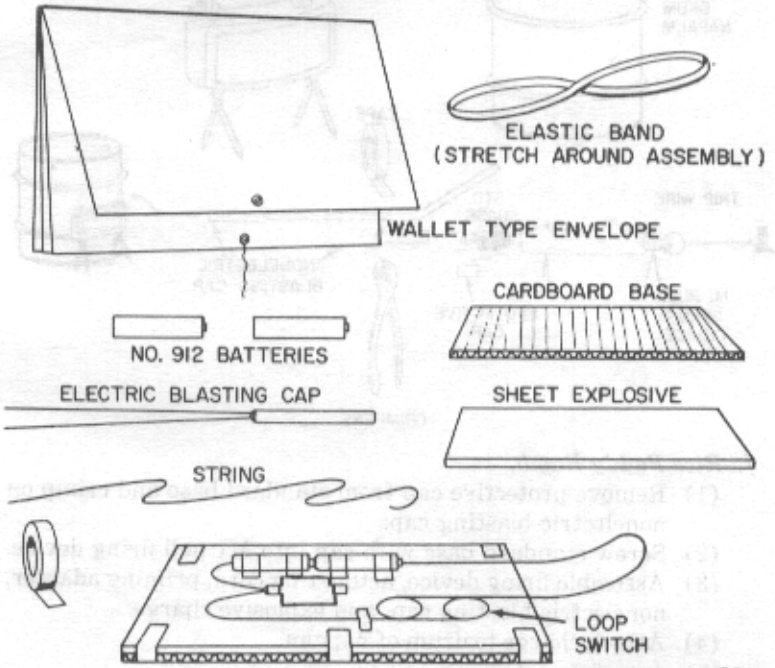
(5) Attach one end of string to loop switch so that it will pull the bared loops together to close circuit.

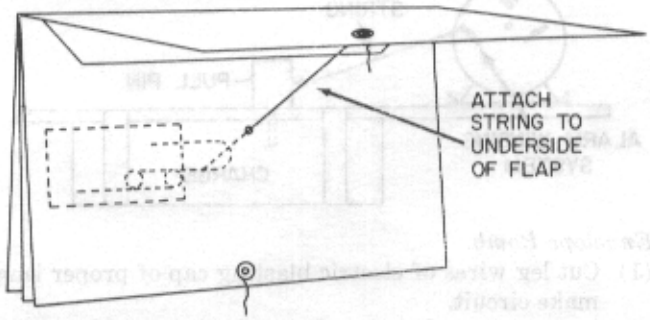
(6) Cut hole inside of envelope under flap.

(7) Fix package in envelope firmly and thread string through hole.

(8) Attach string firmly but concealed to underside of flap.

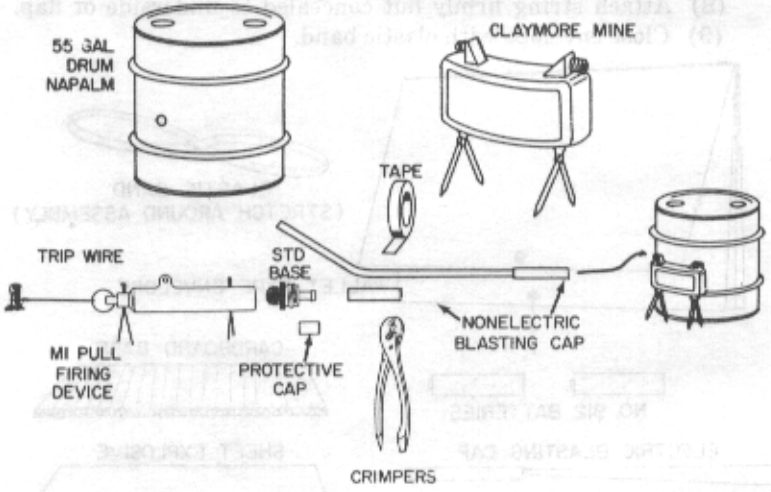
(9) Close envelope with elastic band.





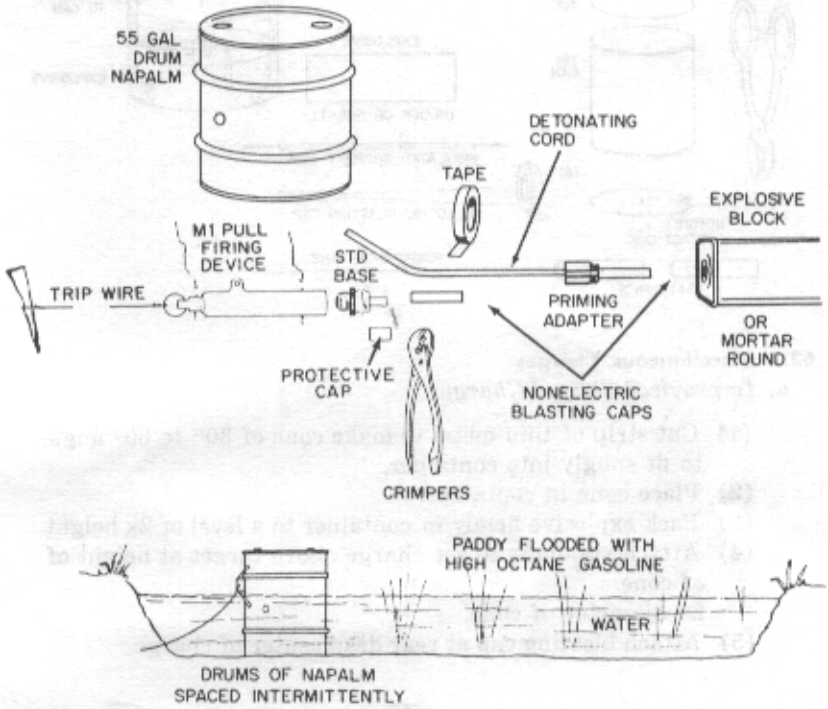
e. Hot Shrapnel Bomb.

(1) Remove protective cap from standard base and crimp on nonelectric blasting cap.
(2) Screw base with cap in M1 pull firing device.
(3) Crimp nonelectric blasting cap on one end of length of detonating cord, and install in Claymore mine.
(4) Attach firing device to detonating cord with tape.
(5) Assemble Claymore mine with priming and firing accessories and drum of napalm.
(6) Arm firing device.



f. Rice Paddy Bomb.

(1) Remove protective cap from standard base and crimp on nonelectric blasting cap.
(2) Screw standard base with cap into M1 pull firing device.
(3) Assemble firing device, detonating cord, priming adapter, nonelectric blasting cap, and explosive charge.
(4) Attach charge to drum of napalm.
(5) Arm firing device.



g. Tin Can Bomb.

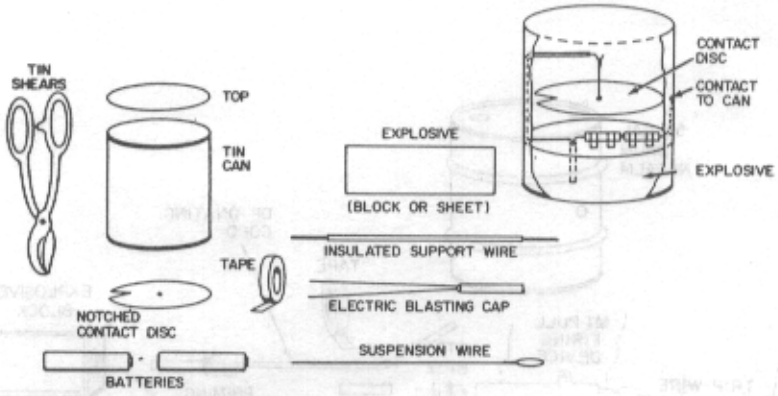
(1) Cut a notched metal contact disk to provide clearance for length of stiff insulated wire and ⅛ to ¼ in. from walls of can.

(2) Cut stiff insulated wire of proper length to support disk and strip insulation from both ends. Bend hook on one end to hold bare suspension wire.

(3) Bend stiff wire to proper shape.

(4) Assemble can, explosive, contact to can, blasting cap, insulated support wire, suspension wire and contact disk.

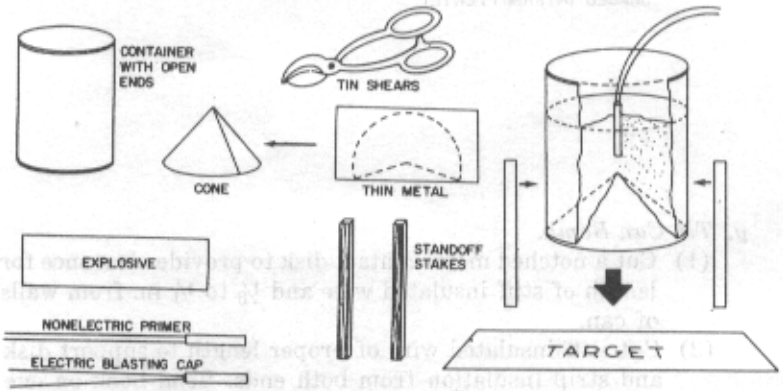
(5) Check circuit with galvonometer *first*, then connect batteries.



62. Miscellaneous Charges

a. Improvised Shaped Charge.

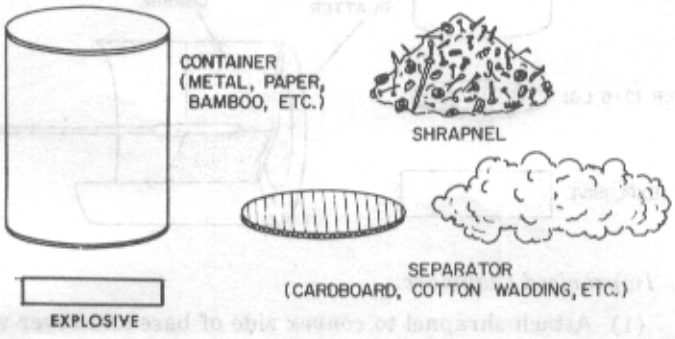
(1) Cut strip of thin metal to make cone of 30° to 60° angle to fit snugly into container.
(2) Place cone in container.
(3) Pack explosive firmly in container to a level of 2x height.
(4) Attach standoffs to set charge above target at height of of cone.
2x diameter of cone.
(5) Attach blasting cap at rear dead center of charge.

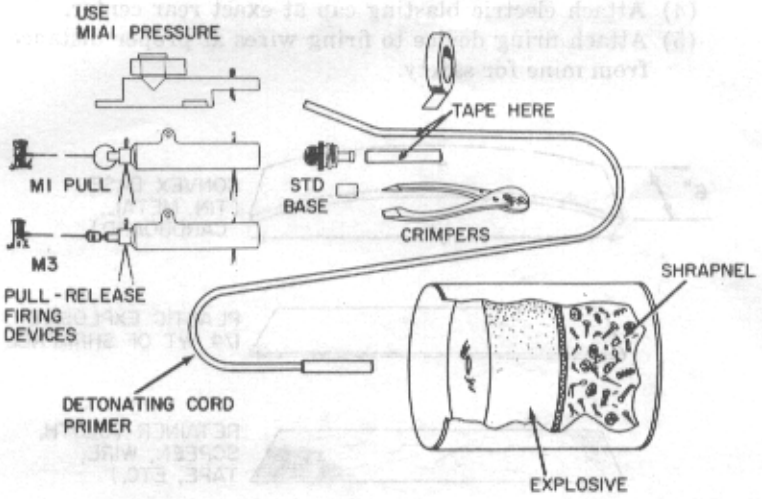


b. Improvised Antipersonnel Mine.

(1) Assemble container, explosive, separator, and shrapnel. *Explosive must be packed to uniform density and thickness* (should be ¼ weight of shrapnel).
(2) Remove protective cap from standard base and crimp on nonelectric blasting cap.

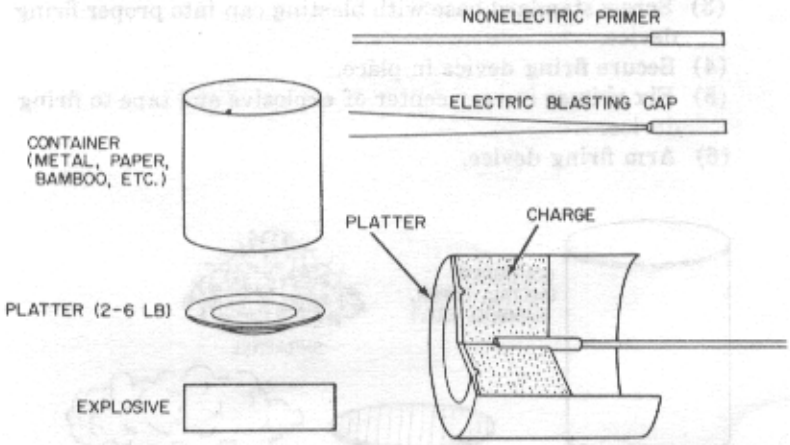
(3) Screw standard base with blasting cap into proper firing device.
(4) Secure firing device in place.
(5) Fix primer in rear center of explosive and tape to firing device.
(6) Arm firing device.





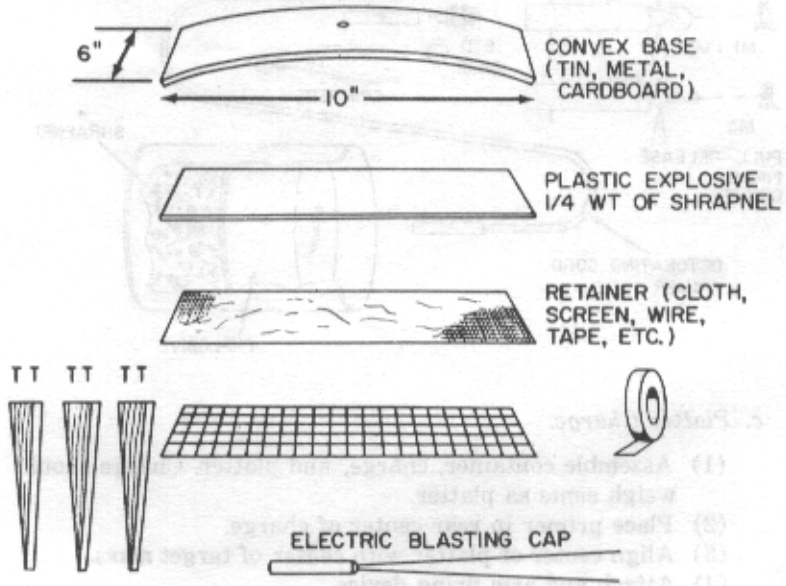
c. Platter Charge.

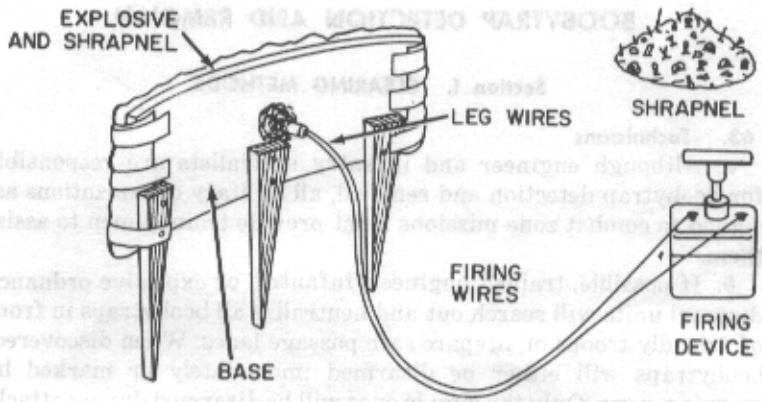
(1) Assemble container, charge, and platter. Charge should weigh same as platter.
(2) Place primer in rear center of charge.
(3) Align center of platter with center of target mass.
(4) Attach and arm firing device.



d. Improvised Claymore.

(1) Attach shrapnel to *convex* side of base and cover with cloth, tape, or screen retainer.
(2) Place layer of plastic explosive on *concave* side of base.
(3) Attach legs to *concave* side of base.
(4) Attach electric blasting cap at exact rear center.
(5) Attach firing device to firing wires at proper distance from mine for safety.




EXPLOSIVE
AND SHRAPNEL
LEG WIRES
SHRAPNEL
FIRING
WIRES
FIRING
DEVICE
BASE

CHAPTER 6

BOOBYTRAP DETECTION AND REMOVAL

Section I. CLEARING METHODS

63. Technicians

a. Although engineer and infantry specialists are responsible for boobytrap detection and removal, all military organizations assigned to combat zone missions must provide trained men to assist them.

b. If possible, trained engineer, infantry, or explosive ordnance disposal units will search out and neutralize all boobytraps in front of friendly troops or prepare safe passage lanes. When discovered, boobytraps will either be disarmed immediately or marked by warning signs. Only the simple ones will be disarmed during attack. Those more complicated will be marked and reported for removal.

c. To avoid casualty, boobytrapped areas, especially villages and other inhabited places, should be bypassed, to be cleared by specialists later. Tactical units will neutralize boobytraps only when necessary for continued movement or operation.

64. Clearance Teams

Men who clear boobytraps are organized into disposal teams and assigned to specific areas according to their training and experience.

a. Direction and control is the responsibility of the person in charge of clearance activities, who will–

(1) Maintain a control point near at hand and remain in close contact with his clearance parties.

(2) Give assistance to disposal teams when required.

(3) Preserve new types of enemy equipment found for more careful examination by engineer intelligence teams.

b. Searching parties will be sufficient in number to cover an area promptly, without interfering with each other.

c. In clearing a building, one person will direct all searching parties assigned.

d. Open area clearance will be preceded by reconnaissance if the presence of boobytraps is suspected. Once boobytraps are found, search must be thorough.

e. Searching parties must be rested frequently. A tired man, or one whose attention is attracted elsewhere, is a danger to himself and others working with him.

65. Tools and Equipment

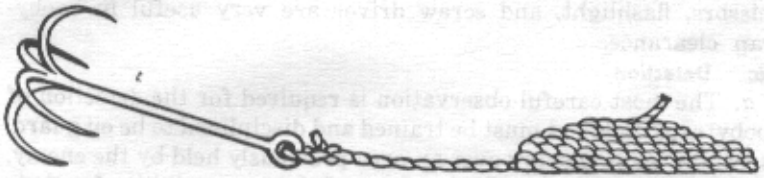
a. Body Armor. Armor of various kinds is available. Special boots and shoe pacs, also issued, will give greater protection against blast than boots generally worn.

b. Mine Detectors.

(1) Three mine detectors useful in the removal of boobytraps are issued: AN/PRS-3 (Polly Smith) and the transistorized, aural indication model, designed for metal detection, and AN/PRS-4 for nonmetallic detection. Of the metal detectors, the transistorized model is the lighter and more powerful. All three models have the same deficiences. They may signal a small piece of scrap as well as a metal-cased explosive or signal an air pocket in the soil, a root, or disturbed soil generally.

(2) Operating time should not exceed 20 minutes to avoid operator fatigue. *Tired operators often become careless operators.*

c. Grapnels. These are hooks attached to a length of stout cord or wire, long enough for the operator to pull a mine or boobytrap from place from a safe distance or from at least 50 meters behind cover.



d. Probes. Lengths of metal rod or stiff wire, or bayonets, are good probes for locating buried charges. Searching parties sometimes work with rolled-up sleeves better to feel trip wires and hidden objects.

e. Markers. Standard markers are carried by disposal teams to designate the location of known boobytraps, pending their removal.

f. Tape. Marking tape is useful for tracing safe routes and identifying dangerous areas.

g. Hand Tools. Small items, such as nails, cotter pins, pieces of wire, friction tape, safety pins, pliers, pocket knife, hand mirror, scissors, flashlight, and screw driver are very useful in boobytrap clearance.

66. Detection

a. The most careful observation is required for the detection of boobytraps. Soldiers must be trained and disciplined to be on guard, especially when moving over an area previously held by the enemy. Although a soldier may not be assigned the responsibility for their detection and clearance, he must be alert for any sign that may indicate their presence. He must also discipline himself to look carefully for concealed boobytraps before performing many acts of normal life.

b. Often prisoners of war through interrogation give information on new or unknown boobytrap devices that may aid in their identification and handling later on. Local inhabitants also often provide information on boobytraps laid in the neighborhood.

c. Searching for boobytraps and delayed charges is difficult and tedious, particularly when intelligence is lacking or inadequate. The extent of search required, the ease of placing and camouflaging, and the great number of devices available to the enemy make the clearance of all charges almost impossible. Searching parties, before being sent out, will be briefed on all that is known about enemy activities in the area.

67. Outdoor Searching Techniques

As boobytraps are so deadly and as a rule cunningly conceived and hidden, outdoor searching parties should be suspicious of -

a. All moveable and apparently valuable and useful property.

b. All disturbed ground and litter from explosive containers.

c. Marks intentionally left behind to attract or divert attention.

d. Evidence of former camouflage.

e. Abrupt changes or breaks in the continuity of any object, such as unnatural appearances of fences, paint, vegetation, and dust.

f. Unnecessary things like nails, wire, or cord that may be part of a boobytrap.

g. Unusual marks that may be an enemy warning of danger.

h. All obstructions, for they are ideal spots for boobytraps. Search carefully before lifting a stone, moving a low hanging limb, or pushing aside a broken-down wheelbarrow.

i. Queer imprints or marks on a road, which may lead a curious person to danger.

j. Abandoned vehicles, dugouts, wells, machinery, bridges, gullies, defiles, or abandoned stores. Also walk carefully in or around these as pressure-release devices are easily concealed under relatively small objects.

k. Areas in which boobytraps are not found immediately. Never assume without further investigation that entire areas are clear.

l. Obvious trip wires. The presence of one trip wire attached to an object does not mean that there are no others. Searching must be complete.

68. Indoor Searching Techniques

Those in charge of disposal teams should:

a. Assign no more than one man to a room in a building.

b. Indicate the finding of a large charge by a prearranged signal. All teams except those responsible for neutralizing large charges must then vacate the building immediately by the original route of entry.

c. Examine both sides of a door before touching a knob. Observe through a window or break open a panel. If doors and windows must be opened and both sides cannot be examined, use a long rope.

d. Move carefully in all buildings, for boobytraps may be rigged to loose boards, moveable bricks, carpets, raised boards or stair treads, window locks, or door knobs.

e. Never move furniture, pictures, or similar objects before checking them carefully for release devices or pull wires.

f. Never open any box, cupboard door, or drawer without careful checking. Sticky doors, drawers, or lids should be pulled with a long rope.

g. Not sit on any chair, sofa, or bed before careful examination.

h. Never connect broken wires or operate switches before checking the entire circuit. Such action may connect power to a charge.

i. Remove all switch plates and trace all wires that appear foreign to a circuit. Examine all appliances.

j. Investigate all repaired areas. Look for arming holes. Enlarge all wall and floor punctures. Cavities may be examined by reflecting a flashlight beam off a hand mirror. (This is also applicable for searching under antitank mines.)

k. Empty all fire boxes, remove the ashes, check fire wood, and move the coal pile.

l. Always work from the basement upward. Check, move, and mark everything movable including valves, taps, levers, controls, screens, and the like. A clockwork delay may not be heard if it is well hidden.

m. Double check basements and first floors—especially chimney flues, elevator and ventilator shafts, and insulated dead-air spaces. Check straight flues and shafts by observing from one end against a light held at the other. Dog-leg flues may be checked by lowering a brick from a safe distance.

n. Guard all buildings until they are occupied.

o. When possible and only after a thorough check, turn on all utilities from *outside* the building.

Note. A soldier by training can develop his sense of danger. Also by experience and careful continuous observation of his surroundings while in a combat area, he can develop an acute instinct that warns him of danger—a most valuable asset toward self-protection.

Section II. DISARMING METHODS

69. Neutralization

a. This is the making of a dangerous boobytrap safe to handle. If this is not possible, however, it must be destroyed. Neutralization involves two steps—*disarming* or replacing safeties in the firing assembly and *defuzing* or separating the firing assembly from the main charge and the detonator from the firing assembly.

b. Although types of boobytraps found in conventional warfare in a combat zone vary greatly, equipment used by most armies is basically similar except in construction details. Accordingly, a knowledge of the mechanical details and techniques in the use of standard U.S. boobytrapping equipment in conventional warfare prepares a soldier to some extent for dealing with that of the enemy. This, however is not true in guerrilla warfare. Most enemy boobytraps found recently in guerrilla infested areas, were cunningly and ingeniously improvised and laid. Such boobytraps can rarely be neutralized even by the most experienced specialists. These are discussed and illustrated in chapter 5.

c. Boobytraps may be neutralized by two methods. (1) Whenever the location permits, they may be destroyed by actuating the mechanism from a safe distance or detonating a charge near the main charge. These should be used at all times unless tactical conditions are unfavorable (2) When necessary, boobytraps may be disassembled by hand. As this is extremely dangerous, it should be

undertaken only by experienced and extremely skillful specialists.

Note. Complete knowledge of the design of the boobytrap should be obtained before any neutralization is attempted.

d. In forward movements, all complicated mechanisms found are bypassed. These are marked and reported for neutralization later, when more deliberate action may be taken without harrassment by enemy fire.

e. All boobytraps exposed to blast from artillery fire or aerial bombing should be destroyed in place.

f. Boobytraps with unrecognizable or complicated firing arrangements should be marked and left for specialists to disarm.

(1) Electrically fired boobytraps are among the most dangerous of all. Though rare in the past, they now turn up frequently in guerrilla warfare. Some may be identified by the presence of electric lead wires, dry cells, or other batteries. Some are small containers with all elements placed inside which actuate at the slightest disturbance. These can hardly be disarmed even by experts.

(2) Another difficult type has delay fuzing—a spring-wound or electric clockwork for long delay periods or chemical action firing devices. As the time of detonation is uncertain, such boobytraps should be destroyed in place, if possible or tactically fesasible.

70. Rules of Conduct

a. Keep in constant practice by inspecting and studying all known boobytrap methods and mechanisms.

b. Develop patience. A careless act may destroy you and others as well.

c. Remember that knowledge inspires confidence.

d. Let only one man deal with a boobytrap. Keep all others out of danger.

e. If in doubt, get help from an expert.

f. Never group together when there is danger.

g. Be suspicious of every unusual object.

h. Regardless of nationality, consider every enemy a ruthless, cunning and ingenious killer.

71. Detailed Operations

a. Destruction in Place.

(1) If damage is acceptable, which is generally the case out of doors, the operator may initiate boobytrap riggings by their own mechanism or by a rope from a safe position (at least 50 meters away).

(2) The easiest method of getting rid of a boobytrap is to detonate a pound of high explosive adjacent to the main charge.

b. Removal of Main Charge (Antitank Mine).

Careful probing or search around the charge is necessary to locate and neutralize all antilift devices. Recognition of the type of firing mechanisms used is necessary to avoid casualty. All safety

devices must be replaced. If complete neutralization seems doubtful, the charge should be pulled from place by a grapnel or rope from a safe location. After the charge is pulled, the operator should wait at least 30 seconds as a safeguard against a concealed delay action fuze.

c. Hand Disarming. None but trained specialists should undertake this job, unless the boobytrap's characteristics and disarming techniques are well known. Trained specialists only should inspect and destroy all unusual or complicated mechanisms for safety reasons and for information on new enemy devices. The following procedures for hand neutralization are for guidance only, as the exact sequence depends on the type of device and the manner of placement.

(1) Do not touch any part of a boobytrap before examining it thoroughly. Locate all firing devices and their triggering mechanisms.

(2) When tracing wires, look for concealed intermediate devices laid to impede searching. Do not disturb any wires during the examination of the boobytrap.

(3) Cut loose trip wires only after careful examination of all connecting objects and their functions and replacing all safeties.

(4) Trace taut wires and disarm all connected firing devices by replacing safeties. Taut wires should be cut only when the danger at both ends has been eliminated.

(5)) Replace safeties in all mechanisms, using nails, lengths of of wire, cotter pins, and other objects.

(6) Never use force in disarming firing devices.

(7) Without disturbing the main charge, cut detonating cord or other leads between the disarmed firing devices and the main charge.

(8) Cut wires leading to an electric detonator—*one at a time.*

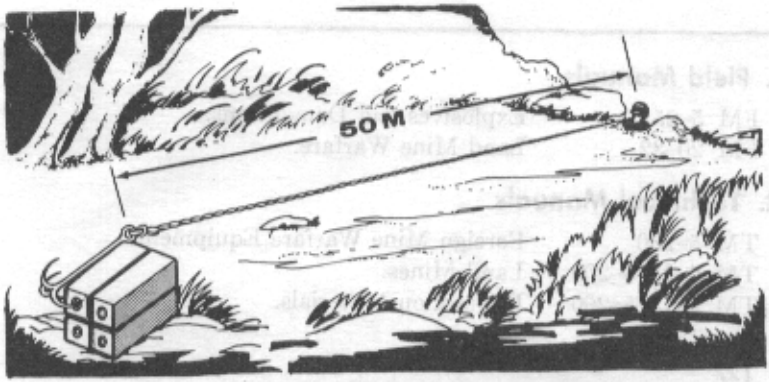
(9) When using a probe, push it gently into the ground. *Stop* when you touch any object. It may be a pressure cap or plate.

(10) Once separated, boobytrap components should be removed to a safe storage or disposal area.

d. Special Precautions.

(1) Be very cautious in handling delay mechanisms. Although there may be little danger before the appointed time, auxiliary firing devices may be present. All complicated and confusing devices should be destroyed in place or marked for treatment by specialists.

(2) Explosive containers of wood or cardboard, buried for long periods are dangerous to disturb. They are also extremely dangerous to probe if in an advanced state of decomposition. Deteriorated high explosives are very susceptible to detonation. Thus destruction in place of a boobytrap and in a concentrated area long exposed to moisture may detonate many others simultaneously.



(3) Metallic explosive containers, after prolonged burial, are often dangerous to remove. Oxidation may make them resistant to detection. After a time the explosive may become contaminated, increasing the danger in handling. Explosives containing picric acid are particularly dangerous as deterioration from contact with metal forms extremely sensitive salts readily detonated by handling.

(4) Fuzes of certain types become extremely sensitive to disturbance from exposure to wet soil. The only safe method of neutralizing or removing such deteriorated boobytraps is detonation in place.

72. Explosive Disposal

a. Usually, explosive items recovered by hand neutralization are destroyed by specially-trained explosive ordnance disposal units. Should untrained troops be required to do this, they should follow established procedures with great care. Explosives to be detonated should be buried in a pit at least 4 feet deep under 2 feet of earth, free of rocks or other matter that may become flying debris.

b. Components should be placed on their side or in position to expose their largest area to the force of the initiating explosive. Demolition blocks should be used for destruction of these components, if available; but bangalore torpedoes or dynamite may be substituted. Primed charges should always be connected to firing mechanisms by detonating cord, so that blasting caps may be connected at the last minute. This eliminates opening the pit in the event of a misfire. All persons engaged in disposal should take cover when explosive components are detonated. Despite the 2-foot layer of earth, fragments may be thrown at high velocity for several hundred yards.

APPENDIX I
REFERENCES

1. Field Manuals

FM 5–25	Explosives and Demolitions.
FM 20–32	Land Mine Warfare.

2. Technical Manuals

TM 5–280	Foreign Mine Warfare Equipment.
TM 9–1345–200	Land Mines.
TM 9–1375–200	Demolition Materials.

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

Official:

J. C. LAMBERT,
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NG: State AG (3); units—same as active Army.
USAR: Units—same as active Army except allowance is one copy to each unit.
For explanation of abbreviations used, see AR 320–50.

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5-250

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 15 June 1992

EXPLOSIVES AND DEMOLITIONS

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Preface

The purpose of this manual is to provide technical information on explosives used by United States military forces and their most frequent applications. This manual does not discuss all applications but presents the most current information on demolition procedures used in most situations.

If used properly, explosives serve as a combat multiplier to deny maneuverability to the enemy. Focusing mainly on these countermobility operations, this manual provides a basic theory of explosives, their characteristics and common uses, formulas for calculating various types of charges, and standard methods of priming and placing these charges.

When faced with unusual situations, the responsible engineer must either adapt one of the recommended demolition methods or design the demolition from basic principles presented in this and other manuals. The officer in charge must maintain ultimate responsibility for the demolition design, ensuring the safe and efficient application of explosives.

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Chapter 1
Military Explosives

Section I. Demolition Materials

1-1. Characteristics. To be suitable for use in military operations, explosives must have certain properties. Military explosives—

- Should be inexpensive to manufacture and capable of being produced from readily available raw materials.
- Must be relatively insensitive to shock or friction, yet be able to positively detonate by easily prepared initiators.
- Must be capable of shattering and must have the potential energy (high energy output per unit volume) adequate for the purpose of demolitions.
- Must be stable enough to retain usefulness for a reasonable time when stored in temperatures between -80 and +165 degrees Fahrenheit.
- Should be composed of high-density materials (weight per unit volume).
- Should be suitable for use underwater or in damp climates.
- Should be minimally toxic when stored, handled, and detonated.

1-2. Selection of Explosives. Select explosives that fit the particular purpose, based on their relative power. Consider all characteristics when selecting an explosive for a particular demolition project. See Technical Manual (TM) 9-1300-214 for detailed information on military explosives. Table 1-1 (page 1-2) contains significant information regarding many of the explosives described below.

1-3. Domestic Explosives.

a. *Ammonium Nitrate.* Ammonium nitrate is the least sensitive of the military explosives. It requires a booster charge to successfully initiate detonation. Because of its low sensitivity, ammonium nitrate is a component of many composite explosives (combined with a more sensitive explosive). Ammonium nitrate is not suitable for cutting or breaching charges because it has a low detonating velocity. However, because of its excellent cratering affects and low cost, ammonium nitrate is a component of most cratering and ditching charges. Commercial quarrying operations use ammonium nitrate demolitions extensively. Pack ammonium nitrate in an airtight container because it is extremely hydroscopic (absorbs humidity). Ammonium nitrate or composite explosives containing ammonium nitrate are not suitable for underwater use unless packed in waterproof containers or detonated immediately after placement.

b. *Pentaerythrite Tetranitrate (PETN).* PETN is a highly sensitive and very powerful military explosive. Its explosive potential is comparable to cyclonite (RDX) and nitroglycerin. Boosters, detonating cord, and some blasting caps contain PETN. It is also used in composite explosives with trinitrotoluene (TNT) or with nitrocellulose. A PETN-nitrocellulose composite (Ml 18 sheet explosive) is a demolition charge. The PETN explosive is a good underwater-demolition because it is almost insoluble in water.

Table 1-1. Characteristics of US demolitions explosives

Name	Applications	Detonation Velocity		RE Factor*	Fume Toxicity	Water Resistance
		M/Sec	Ft/Sec			
Black Powder	Time Fuse	400	1,300	0.55	Dangerous	Poor
Ammonium Nitrate	Cratering Charge	2,700	8,900	0.42	Dangerous	Poor
Amatol 80/20	Bursting Charge	4,900	16,000	1.17	Dangerous	Poor
M1 Dynamite	Demolition Charge	6,100	20,000	0.92	Dangerous	Fair
Detonating Cord	Priming	6,100 to 7,300	20,000 to 24,000	—	Slight	Excellent
TNT	Demolition Charge Composition Explosive	6,900	22,600	1.00	Dangerous	Excellent
Tetrytol 75/25	Demolition Charge	7,000	23,000	1.20	Dangerous	Excellent
Tetryl	Booster Charge Composition Explosive	7,100	23,300	1.25	Dangerous	Excellent
Sheet Explosive M118 and M186	Cutting Charge	7,300	24,000	1.14	Dangerous	Excellent
Pentolite 50/50	Booster Charge Bursting Charge	7,450	24,400	—	Dangerous	Excellent
Nitroglycerin	Commercial Dynamite	7,700	25,200	1.50	Dangerous	Good
Bangalore Torpedo, M1A2	Demolition Charge	7,800	25,600	1.17	Dangerous	Excellent
Shaped Charges M2A3, M2A4, and M3A1	Cutting Charge	7,800	25,600	1.17	Dangerous	Excellent
Composition B	Bursting Charge	7,800	25,600	1.35	Dangerous	Excellent
Composition C4 and M112	Cutting Charge Breaching Charge	8,040	26,400	1.34	Slight	Excellent
Composition A3	Booster Charge Bursting Charge	8,100	26,500	—	Dangerous	Good
PETN	Detonating Cord Blasting Caps Demolition Charges	8,300	27,200	1.66	Slight	Excellent
RDX	Blasting Caps Composition Explosives	8,350	27,400	1.60	Dangerous	Excellent
*TNT equals 1.00						

c. *Cyclotrimethlenetrinitramine (RDX). RDX* is also a highly sensitive and very powerful military explosive. It forms the base charge in the M6 electric and M7 nonelectric blasting caps. When RDX is desensitized, it serves as a subbooster, booster, bursting charge, or demolition charge. The principal use for RDX is in composite explosives, such as Composition A, B, and C explosives. RDX is available commercially under the name cyclonite.

d. *Trinitrotoluene.* TNT is the most common military explosive. It maybe in composite form, such as a booster, a bursting, or a demolition charge, or in a noncomposite form. Since TNT is a standard explosive, it is used to rate other military explosives.

e. *Tetryl.* Tetryl is an effective booster charge in its noncomposite form and a bursting or a demolition charge in composite forms. Tetryl is more sensitive and powerful than TNT. However, RDX- and PETN-based explosives, which have increased power and shattering effects, are replacing tetryl and composite explosives containing tetryl.

f. *Nitroglycerin.* Nitroglycerin is one of the most powerful high explosives. Its explosive potential is comparable to RDX and PETN. Nitroglycerin is the explosive base for commercial dynamites. Nitroglycerine is highly sensitive and extremely temperature-sensitive. Military explosives do not use nitroglycerin because of its sensitivity. Do not use commercial dynamites in combat areas.

g. *Black Powder.* Black powder is the oldest-known explosive and propellant. It is a composite of potassium or sodium nitrate, charcoal, and sulfur. Time fuses, some igniters, and some detonators contain black powder.

h. *Amatol.* Amatol is a mixture of ammonium nitrate and TNT. It is a substitute for TNT in bursting charges. Some older bangalore torpedoes use 80-20 amatol (80 percent ammonium nitrate and 20 percent TNT). Because amatol contains ammonium nitrate, it is a hydroscopic compound. Keep any explosives containing amatol in airtight containers. If properly packaged, amatol remains viable for long periods of time, with no change in sensitivity, power, or stability.

i. *Composition A3.* Composition A3 is a composite explosive containing 91 percent RDX and 9 percent wax. The purpose of the wax is to coat, desensitize, and bind the RDX particles. Composition A3 is the booster charge in some newer shaped charges and bangalore torpedoes. High-explosive plastic (HEP) projectiles may also contain Composition A3 as a main charge.

j. *Composition B.* Composition B is a composite explosive containing approximately 60 percent RDX, 39 percent TNT, and 1 percent wax. It is more sensitive than TNT. Because of its shattering power and high rate of detonation, Composition B is the main charge in shaped charges.

k. *Composition B4.* Composition B4 contains 60 percent RDX, 39.5 percent TNT, and 0.5 percent calcium silicate. Composition B4 is the main charge in newer models of bangalore torpedoes and shaped charges.

l. *Composition C4 (C4). C4* is a composite explosive containing 91 percent RDX and 9 percent nonexplosive plasticizers. Burster charges are composed of C4. C4 is effective in temperatures between -70 to+ 170 degrees Fahrenheit; however, C4 loses its plasticity in the colder temperatures.

m. *Tetrytol.* Tetrytol is a composite explosive containing 75 percent tetryl and 25 percent TNT. It is the explosive component in demolition charges. Booster charges require different mixtures of tetryl and TNT. Tetrytol is more powerful than its individual components, is better at shattering than TNT, and is less sensitive than tetryl.

n. *Pentolite.* Pentolite is a mixture of PETN and TNT. Because of its high power and detonating rate, a mixture of 50-50 pentolite (50 percent PETN and 50 percent TNT) makes an effective booster charge in certain models of shaped charges.

o. Dynamites.

(1) Standard Dynamite. Most dynamites, with the notable exception of military dynamite, contain nitroglycerin plus varying combinations of absorbents, oxidizers, antacids, and freezing-point depressants. Dynamites vary greatly in strength and sensitivity depending on, among other factors, the percentage of nitroglycerin they contain. Dynamites are for general blasting and demolitions, including land clearing, cratering and ditching, and quarrying.

(2) Military Dynamite. Military dynamite is a composite explosive that contains 75 percent RDX, 15 percent TNT, and 10 percent desensitizers and plasticizers. Military dynamite is not as powerful as commercial dynamite. Military dynamite's equivalent strength is 60 percent of commercial dynamiters. Because military dynamite contains no nitroglycerin, it is more stable and safer to store and handle than commercial dynamite.

1-4. Foreign Explosives.

a. *Composition.* Foreign countries use a variety of explosives, including TNT, picric acid, amatol, and guncotton. Picric acid is similar to TNT, but it also corrodes metals and thus forms extremely sensitive compounds.

WARNING
Do not use picric acid in rusted or corroded metal containers.
Do not handle picric acid. Notify explosive ordnance disposal (EOD) personnel for disposition.

b. *Use.* You may use the explosives of allied nations and those captured from the enemy to supplement standard supplies. Only expert demolitionists should use such explosives and then only according to instructions and directives of theater commanders. Captured bombs, propellants, and other devices may be used with US military explosives for larger demolition projects, such as pier, bridge, tunnel, and airfield destruction. Most foreign explosive blocks have cap wells large enough to receive US military blasting caps. Since foreign explosives may differ from US explosives in sensitivity and force, test shots should be made to determine their adequacy before extensive use or mixing with US-type explosives.

Section II. Service Demolition Charges

1-5. Block Demolition Charges. Block demolition charges are prepackaged, high-explosive charges for general demolition operations, such as cutting, breaching, and cratering. They are composed of the high-explosive TNT, tetrytol, Composition-C series, and ammonium nitrate. Block charges are rectangular inform except for the 40-pound, ammonium-nitrate block demolition charge, military dynamite, and the ¼-pound-TNT block demolition charge, which are all cylindrical in form. The various block charges available are described in the text that follows, as well as Table 1-2. See TM 43-0001-38 for detailed information about demolition charges and accessories.

Table 1-2. Characteristics of block demolition charges

Explosive	Unit (Pounds)	Size (Inches)	Detonation Velocity		RE Factor	Packaging/ Weight[2]
			M/Sec	Ft/Sec		
TNT	0.25	1½ D x 3½ L	6,900	22,600	1.00	200 per Box/55 Lb
	0.50	1¾ x 1¾ x 3¾	6,900	22,600	1.00	96 per Box/53 Lb
	1.00	1¾ x 1¾ x 7	6,900	22,600	1.00	48 per Box/53 Lb
M112 Block[1]	1.25	1 x 2 x 10	8,040	26,400	1.34	30 per Box/40 Lb
M118 Block	2.00	1 x 3 x 12	7,300	24,000	1.14	4 Sheets per Block; 20 per Box/ 42 Lb
M118 Sheet[1]	0.50	¼ x 3 x 12	7,300	24,000	1.14	
M186 Roll	25.00	¼ x 3 x 50 ft	7,300	24,000	1.14	3 per Box/80 Lb
Ammonium Nitrate	43.00	7 x 24	3,400	11,000	0.42	1 per Box/52 Lb
M1 Dynamite	0.50	1¼ D x 8 L	6,100	20,000	0.92	100 per Box/62 Lb

[1]The volume of M112 is 20 cubic inches. The volume of one sheet of M118 is 9 cubic inches.
[2]Packaging weights include packaging material and weight of container.

1-6. TNT Block Demolition Charge.

a. *Characteristics.* TNT block demolitions, shown in Figure 1-1, are available in three sizes (Table 1-2). The ¼-pound block is issued in a cylindrical, waterproof, olive-drab cardboard container. The ½-pound and l-pound blocks are available in similar rectangular containers. All of the three charges have metal ends with a threaded cap well in one end.

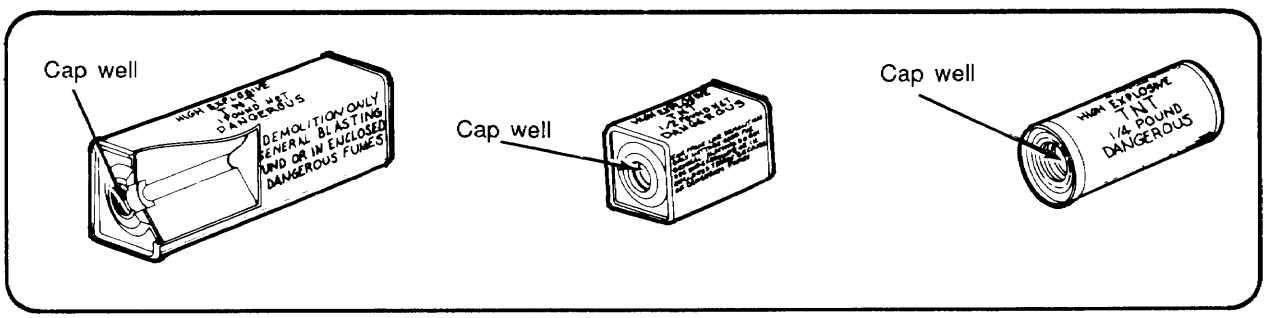


Figure 1-1. TNT block demolition charges

b. *Use.* TNT block demolition charges are effective for all types of demolition work. However, the ¼-pound charge is primarily for training purposes.

c. *Advantages.* TNT demolition charges have a high detonating velocity. They are stable, relatively insensitive to shock or friction, and water resistant. They also are conveniently sized, shaped, and packaged.

d. *Limitations.* TNT block demolition charges cannot be molded and are difficult to use on irregularly shaped targets. TNT is not recommended for use in closed spaces because one of the products of explosion is poisonous gases.

1-7. M112 Block Demolition Charge.

a. *Characteristics.* The M112 block demolition charge consists of 1.25 pounds of C4 packed in an olive-drab, Mylar-film container with a pressure-sensitive adhesive tape on one surface (Figure 1-2). The tape is protected by a peelable paper cover. Table 1-2 (page 1-5) lists additional characteristics of the Ml12 block.

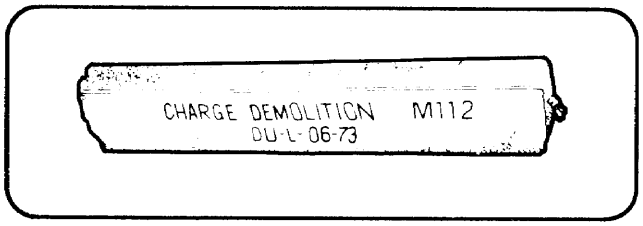


Figure 1-2. M112 block demolition charge

b. *Use.* The M112 block demolition charge is used primarily for cutting and breaching. Because of its high cutting effect and its ability to be cut and shaped, the M1l2 charge is ideally suited for cutting irregularly shaped targets such as steel. The adhesive backing allows you to place the charge on any relatively flat, clean, dry surface with a temperature that is above the freezing point. The Ml12 charge is the primary block demolition charge presently in use.

WARNING

Composition C4 explosive is poisonous and dangerous if chewed or ingested; its detonation or burning produces poisonous fumes. Cut all plastic explosives with a sharp steel knife on a nonsparking surface. Do not use shears.

c. Advantages. You can cut to shape the M112 block demolition charge to fit irregularly shaped targets. The color of the wrapper helps camouflage the charge. Molding the charge will decrease its cutting effect.

d. *Limitations.* The adhesive tape will not adhere to wet, dirty, rusty, or frozen surfaces.

1-8. M118 Block Demolition Charge.

a. *Characteristics.* The M118 block demolition charge, or sheet explosive, is a block of four ½-pound sheets of flexible explosive packed in a plastic envelope (Figure 1-3). Twenty Ml18 charges and a package of 80 M8 blasting-cap holders are packed in a wooden box. Each sheet of the explosive has a pressure-sensitive adhesive tape attached to one surface. Table 1-2 (page 1 -5) lists additional characteristics for the M118 charge.

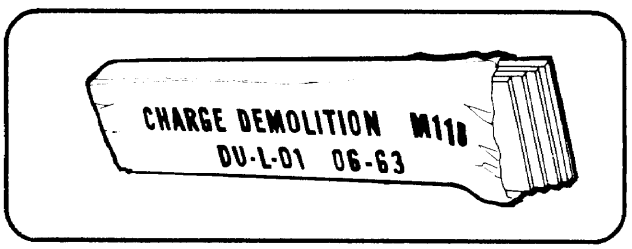


Figure 1-3. M118 block demolition charge

b. *Use.* The Ml18 charges are designed for cutting, especially against steel targets. The sheets of explosive are easily and quickly applied to irregular and curved surfaces and are easily cut to any desired dimension. The Ml18 charge is effective as a small breaching charge but, because of its high cost, it is not suitable as a bulk explosive charge.

c. Advantages. The flexibility and adhesive backing of the sheets allow application to a large variety of targets. You can cut the ½-pound sheets to any desired dimension and apply them in layers to achieve the desired thickness. The Ml18 charge is not affected by water, making it acceptable for underwater demolitions.

d. *Limitations.* The adhesive tape will not adhere to wet, dirty, rusty, or frozen surfaces.

1-9. M186 Roll Demolition Charge.

a. *Characteristics.* The Ml86 roll demolition charge, shown in Figure 1-4, is identical to the Ml18 block demolition charge except that the sheet explosive is in roll form on a 50-foot, plastic spool. Each foot of the roll provides approximately a half pound of explosive. Included with each roll are 15 M8 blasting cap holders and a canvas bag with carrying strap. Table 1-2 (page 1-5) lists additional characteristics for the M186 charge.

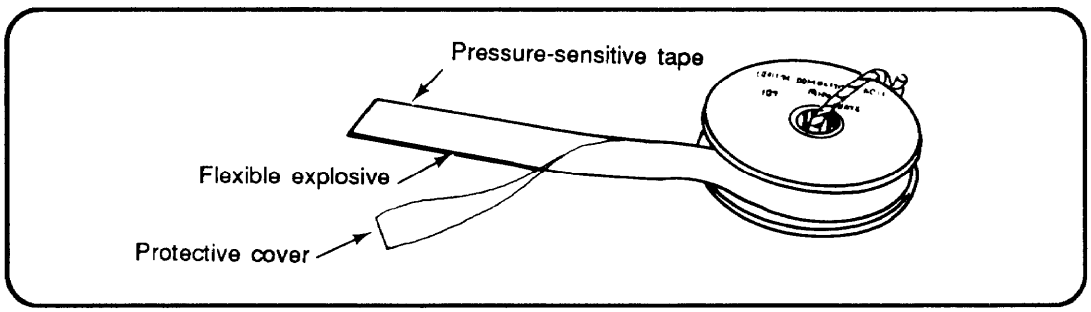


Figure 1-4. M186 roll demolition charge

b. *Use.* Use the M186 roll demolition charge in the same manner as the Ml18 block demolition charge. The Ml86 charge is adaptable for demolishing targets that require the use of flexible explosives in lengths longer than 12 inches.

c. *Advantages.* The Ml86 roll demolition charge has all the advantages of the Ml18 block demolition charge. You can cut the M186 charge to the exact lengths desired.

d. *Limitations.* The adhesive backing will not adhere to wet, dirty, rusty, or frozen surfaces.

1-10. Forty-Pound, Ammonium-Nitrate Block Demolition Charge

a. *Characteristics.* Figure 1-5 (page 1-8) shows the 40-pound, ammonium-nitrate block demolition charge or cratering charge. It is a watertight, cylindrical metal container with approximately 30 pounds of an ammonium-nitrate-based explosive and 10 pounds of TNT-based explosive booster in the center, next to the priming tunnels. The two priming tunnels are located to the outside of the container, midway between the ends. One tunnel serves as a cap well for priming the charge with an M6 electric or M7 nonelectric military blasting cap. The other tunnel series as a priming path, with the detonating cord passing through the tunnel and knotted at the end. There is a cleat between the tunnels to secure the time blasting fuse, electrical firing wire, or detonating cord. There is a metal ring on the top of the container for lowering the charge into its hole. Table 1-2 (page 1-5) lists additional characteristics for the 40-pound, ammonium-nitrate block demolition charge.

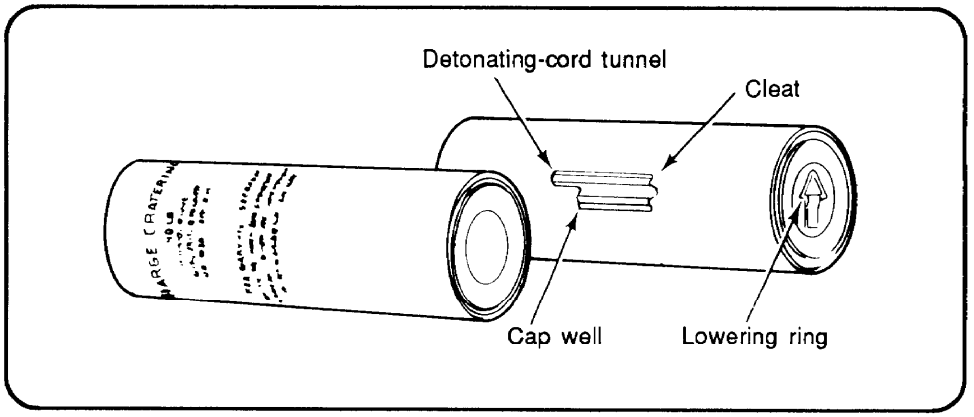


Figure 1-5. Forty-pound, ammonium-nitrate cratering charge

b. *Use.* This charge is suitable for cratering and ditching operations. Its primary use is as a cratering charge, but it also is effective for destroying buildings, fortifications, and bridge abutments.

c. *Advantages.* The size and shape of this charge make it ideal for cratering operations. It is inexpensive to produce compared to other explosives.

d. *Limitations.* Ammonium nitrate is hydroscopic. When wet, it will not detonate. To ensure detonation, use metal containers showing no evidence of water damage. Detonate all charges placed in wet or damp boreholes as soon as possible.

1-11. Ml Military Dynamite.

a. *Characteristics.* M1 military dynamite is an RDX-based composite explosive containing no nitroglycerin (Figure 1-6). M 1 dynamite is packaged in ½-pound, paraffin-coated, cylindrical paper cartridges, which have a nominal diameter of 1.25 inches and a nominal length of 8 inches. Table 1-2 (page 1-5) lists additional characteristics for Ml military dynamite.

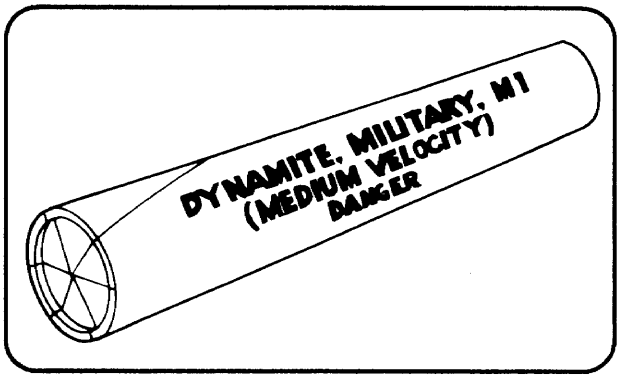


Figure 1-6. M1 military dynamite

b. *Use.* Ml dynamite's primary uses are military construction, quarrying, ditching, and service demolition work. It is suitable for underwater demolitions.

c. *Advantages.* Ml dynamite will not freeze or perspire in storage. The Ml dynamite's composition is not hydroscopic. Shipping containers do not require turning during storage. Ml dynamite is safer to store, handle, and transport than 60-percent commercial dynamite. Unless essential, do not use civilian dynamite in combat areas.

d. *Limitations.* Ml dynamite is reliable underwater only for 24 hours. Because of its low sensitivity, pack sticks of military dynamite well to ensure complete detonation of the charge. Ml dynamite is not efficient as a cutting or breaching charge.

Section III. Special Demolition Charges and Assemblies

1-12. Shaped Demolition Charge. The shaped demolition charge used in military operations is a cylindrical block of high explosive. It has a conical cavity in one end that directs the cone-lining material into a narrow jet to penetrate materials (Figure 1-7). This charge is not effective underwater, since any water in the conical cavity will prevent the high-velocity jet from forming. To obtain maximum effectiveness, place the cavity at the specified standoff distance from the target, and detonate the charge from the exact rear center, using only the priming well provided. Never dual prime a shaped charge.

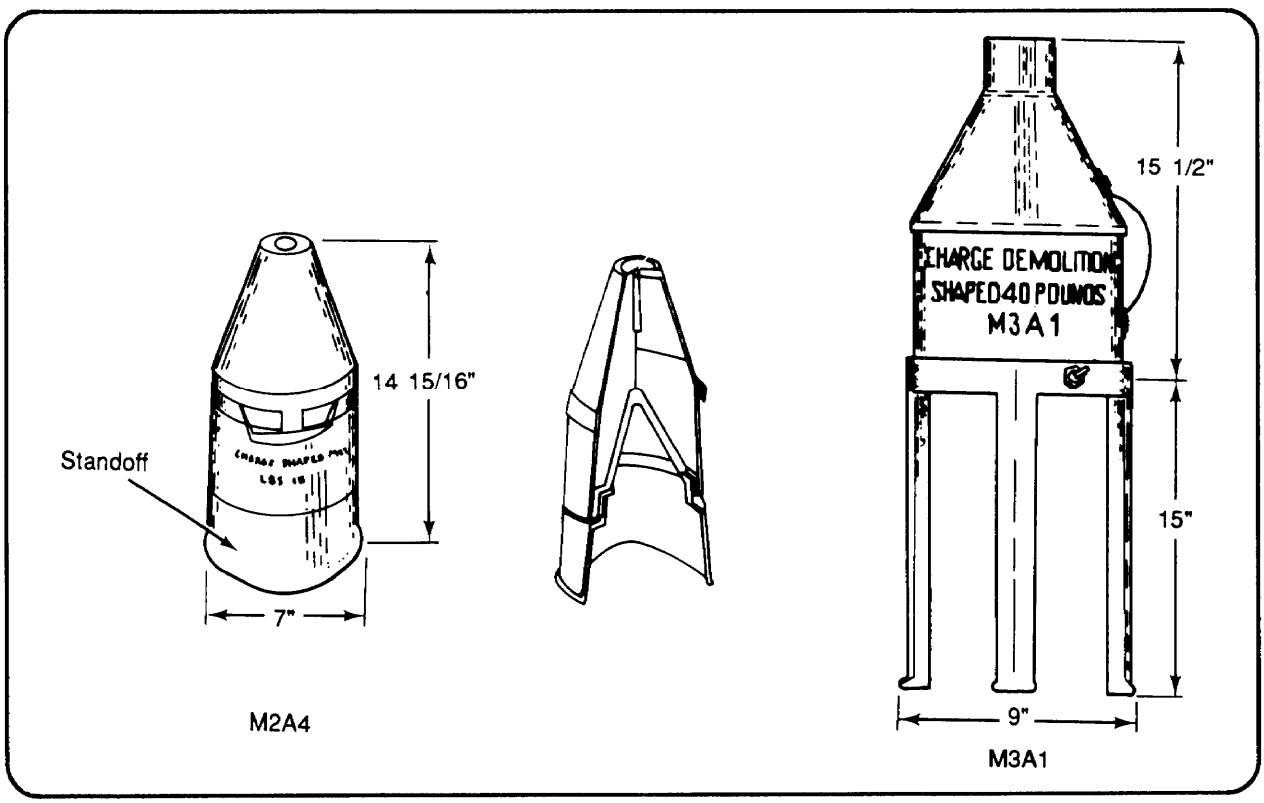


Figure 1-7. Shaped charges

a. *Characteristics.*

(1) Fifteen-Pound, M2A4 Shaped Demolition Charge. The M2A4 charge contains a 0.1 l-pound (50 gram) booster of Composition A3 and a 11.5-pound main charge of Composition B. It is packaged three charges per wooden box (total weight is 65 pounds). This charge has a moisture-resisting, molded-fiber container. A cylindrical fiber base slips onto the end of the charge to provide a 6-inch standoff distance. The cavity liner is a cone of glass. The charge is 14 $^{15}/_{16}$ inches high and 7 inches in diameter, including the standoff.

(2) Forty-Pound, M3A1 Shaped Demolition Charge. The M3A1 charge contains a 0.1 l-pound (50 gram) booster of Composition A3 and a 29.5-pound main charge of Composition B. It is packaged one charge per box (total weight is 65 pounds). The charge is in a metal container. The cone liner also is made of metal. A metal tripod provides a 15-inch standoff distance. The charge is 15 ½ inches high and 9 inches in diameter, not including standoff.

b. *Use.* A shaped demolition charge's primary use is for boring holes in earth, metal, masonry, concrete, and paved and unpaved roads. Its effectiveness depends largely on its shape, composition, and placement. Table 1-3, lists the penetrating capabilities of various materials and the proper standoff distances for these charges.

Table 1-3. Characteristics of boreholes made by shaped charges

Material	Specifications	M2A4 Shaped Charge (15-Pound)*	M3A1 Shaped Charge (40-Pound)**
Armor plate	Penetration	12.00 in	At least 20.00 in
	Average hole diameter	1.50 in	2.50 in
Reinforced concrete	Maximum wall thickness	36.00 in	60.00 in
	Penetration depth in thick walls	30.00 in	60.00 in
	Average hole diameter	2.75 in	3.50 in
	Minimum hole diameter	2.00 in	2.00 in
Concrete pavement (10-inch with 21-inch rock base course)	Optimum standoff	42.00 in	60.00 in
	Minimum penetration depth	44.00 in	71.00 in
	Maximum penetration depth	91.00 in	109.00 in
	Minimum hole diameter	1.75 in	6.75 in
Concrete pavement (3-inch with 24-inch rock base course)	Optimum standoff	42.00 in	—
	Minimum penetration depth	38.00 in	—
	Maximum penetration depth	90.00 in	—
	Minimum hole diameter	3.75 in	—
Permafrost	Hole depth (30-inch standoff)	72.00 in	—
	Hole depth (42-inch standoff)	60.00 in	—
	Hole depth (50-inch standoff)	—	72.00 in
	Hole diameter (42-inch standoff)	1.50 to 6.00 in	—
	Hole diameter (50-inch standoff)	—	5.00 to 8.00 in
	Hole diameter (normal standoff)	4.00 to 30.00 in	7.00 to 30.00 in
Ice	Hole depth (42-inch standoff)	7.00 ft	12.00 ft
	Hole diameter (42-inch standoff)	3.50 in	6.00 in
Soil	Hole depth (30-inch standoff)	7.00 ft	—
	Hole depth (48-inch standoff)	—	7.00 ft
	Hole diameter (30-inch standoff)	7.00 in	—
	Hole diameter (48-inch standoff)	—	14.50 in
Graveled roads	Hole depth (30-inch standoff)	7.00 ft	—
	Hole depth (48-inch standoff)	—	9.00 ft
	Hole diameter (30-inch standoff)	7.00 in	—
	Hole diameter (48-inch standoff)	—	7.00 in

*A dash in the M2A4 Shaped Charge column indicates that a M3A1 shaped charge is required.
**A dash in the M3A1 Shaped Charge column indicates that a M2A4 shaped charge is sufficient.

c. *Special Precautions.* To achieve the maximum effectiveness of shaped charges—

- Center the charge over the target point.
- Align the axis of the charge with the direction of the desired hole.
- Use the pedestal to obtain the proper standoff distance.

- Suspend the charge at the proper height on pickets or tripods, if the pedestal does not provide the proper standoff distance.
- Remove any obstruction in the cavity liner or between the charge and the target.

1-13. M183 Demolition Charge Assembly.

a. *Characteristics.* The Ml83 demolition charge assembly or *satchel charge* consists of 16 M112 (C4) demolition blocks and 4 priming assemblies. It has a total explosive weight of 20 pounds. The demolition blocks come in two bags, eight blocks per bag. The two bags come in an M85 canvas carrying case. Two M85 cases come in a wooden box 17 1/8 by 11½ by 12½ inches. Each priming assembly consists of a 5-foot length of detonating cord with an RDX booster crimped to each end and a pair of Ml detonating-cord clips for attaching the priming assembly to a detonating cord ring or line main.

b. *Use.* The M183 assembly is used primarily forereaching obstacles or demolishing structures when large demolition charges are required (Figure 1-8). The M183 charge also is effective against smaller obstacles, such as small dragon's teeth.

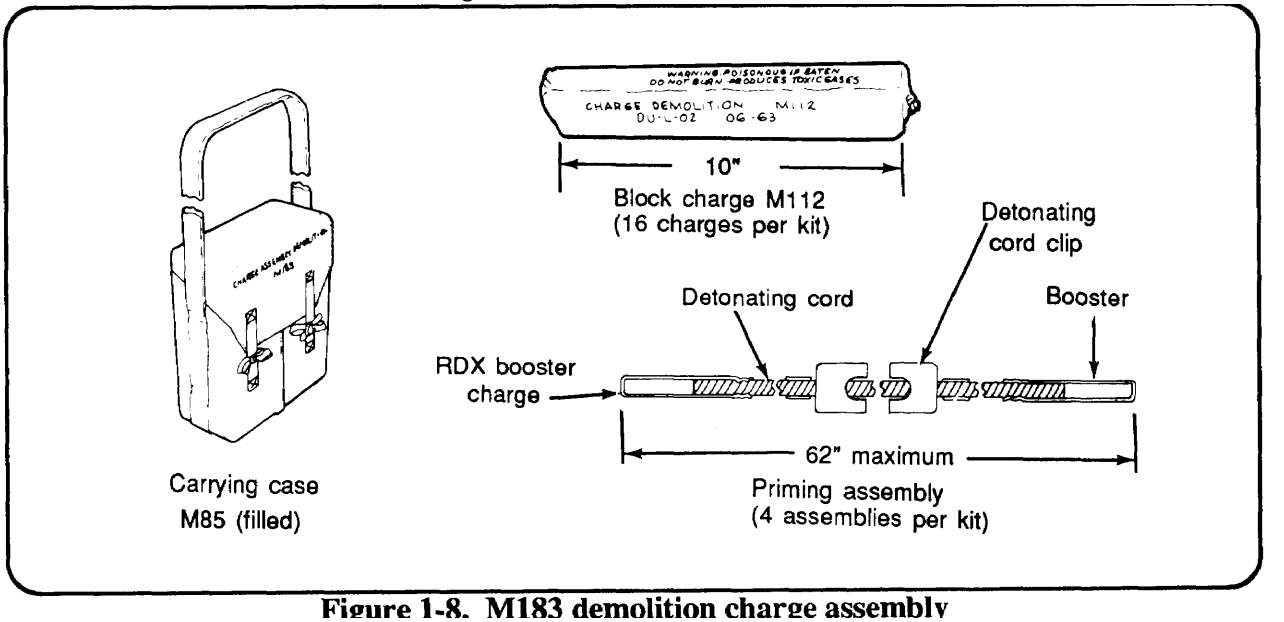


Figure 1-8. M183 demolition charge assembly

c. *Detonation.* Detonate the Ml83 demolition charge assembly with a priming assembly and an electric or a nonelectric blasting cap or by using a detonating-cord ring main attached by detonating cord clips.

1-14. M1A2 Bangtlore-Torpedo Demolition Kit.

a. *Characteristics.* Each kit consists of 10 loading assemblies, 10 connecting sleeves, and 1 nose sleeve. The loading assemblies, or torpedoes, are steel tubes 5 feet long and 2 1/8 inches in diameter, grooved, and capped at each end (Figure 1-9, page 1-12). The torpedoes have a 4-inch, Composition A3 booster (½ pound each) at both ends of each 5-foot section. The main explosive charge is 10½ pounds of Composition B4. The kit is packaged in a 60¾- by 13¾- by 4 9/16-inch wooden box and weighs 198 pounds.

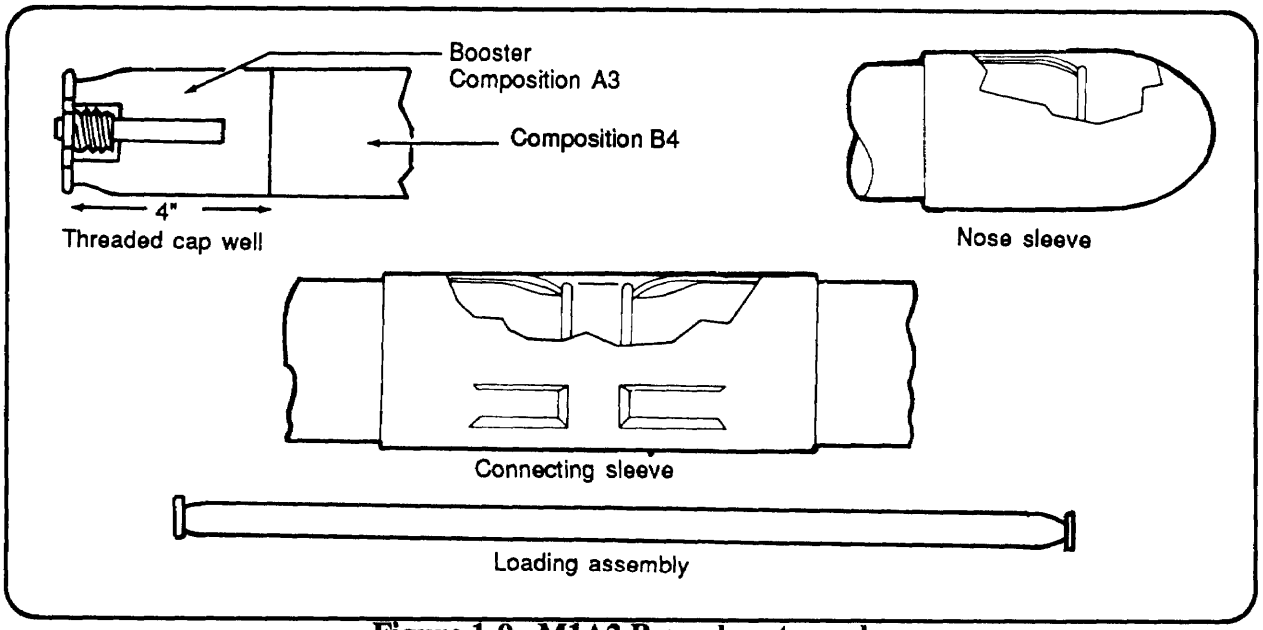


Figure 1-9. M1A2 Bangalore torpedo

b. *Use.* The primary use of the torpedo is clearing paths through wire obstacles and heavy undergrowth. It will clear a 3- to 4-meter-wide path through wire obstacles.

WARNING
The Bangalore torpedo may detonate a live mine when being placed. To prevent detonation of the torpedo during placement, attach the nose sleeve to a fabricated dummy section (approximately the same dimensions as a single Bangalore section) and place the dummy section onto the front end of the torpedo.

c. *Assembly.* All sections of the torpedo have threaded cap wells at each end. To assemble two or more sections, press a nose sleeve onto one end of one tube, and then connect successive tubes, using the connecting sleeves provided until you have the desired length. The connecting sleeves make rigid joints. The nose sleeve allows the user to push the torpedo through entanglements and across the ground.

d. *Detonation.* The recommended method to detonate the torpedo is to prime the torpedo with eight wraps of detonating cord and attach two initiation systems for detonation. Another method for priming the Bangalore torpedo is by inserting an electric or a nonelectric blasting cap directly into the cap well. Do not move the torpedo after it has been prepared for detonation. You may wrap the end with detonating cord prior to placing it, but do not attach the blasting caps until the torpedo is in place.

1-15. M180 Demolition Kit (Cratering).

a. *Characteristics.* This kit consists of an M2A4 shaped charge, a modified M57 electrical firing device, a warhead, a rocket motor, a tripod, and a demolition circuit (Figure 1- 10). The shaped charge, firing device, and warhead are permanently attached to the launch leg of the tripod. The rocket motor and the demolition circuit (packed in a wooden subpack) are shipped separately. The

kit weighs approximately 165 pounds (74.25 kilograms). TM 9-1375-213-12-1 provides the assembly procedures, operational description, and maintenance instructions for the Ml80 kit.

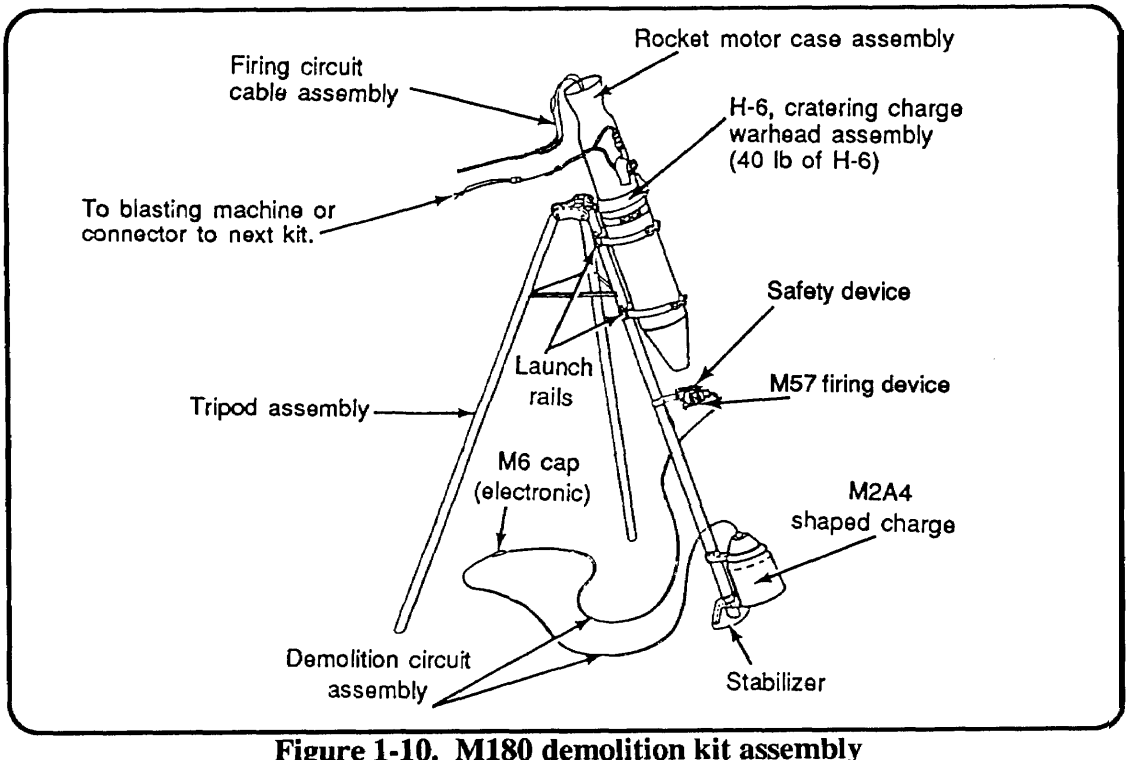


Figure 1-10. M180 demolition kit assembly

b. *Use.* The M180 is designed to produce a large crater in compacted soil or road surfaces, but not in reinforced concrete, arctic tundra, bedrock, or sandy soil. The charge produces a crater in two stages. The shaped charge blows a pilot hole in the surface. Then, the rocket-propelled warhead enters the hole and detonates, enlarging the pilot hole. Up to five kits can be set up close together and fired simultaneously to produce an exceptionally large crater. Up to 15 kits can be widely spaced and freed simultaneously for airfield pocketing.

WARNING
Regardless of the number of kits used, the minimum safe distances for the M180 cratering kit are 1,200 meters for unprotected personnel and 150 meters for personnel under overhead cover.

c. *Detonation.* When firing the M180, use the M34 50-cap blasting machine.

Section IV. Demolition Accessories

1-16. Time Blasting Fuse. The time blasting fuse transmits a delayed spit of flame to a nonelectric blasting cap. The delay allows the soldier to initiate a charge and get to a safe distance before the explosion. There are two types of fuses: the M700 time fuse and safety fuse. Although safety fuse is not often employed, it is still available.

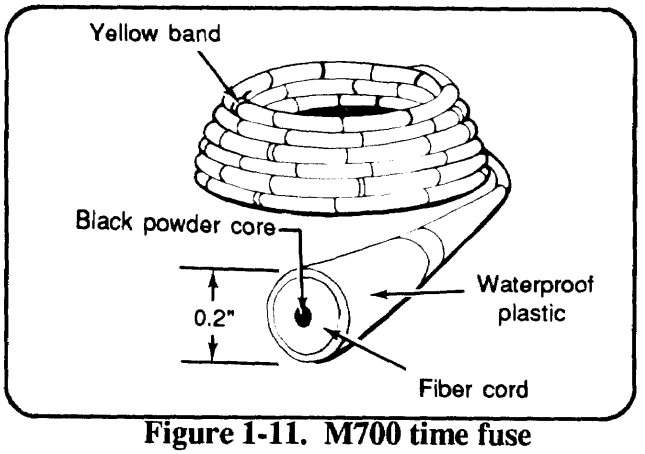


Figure 1-11. M700 time fuse

a. *M700 Time Fuse.* The M700 fuse is a dark green cord, 0.2 inches in diameter, with a plastic cover (Figure 1-1 1). The M700 bums at an approximate rate of 40 seconds per foot. However, test the burning rate as outlined in Chapter 2 (paragraph 2-lb(l), page 2-2). Depending on the date of manufacture, the cover may be smooth or have single yellow bands around the outside at 12- or 18-inch intervals and double yellow bands at 60- or 90-inch intervals. These bands accommodate hasty measuring. The outside covering becomes brittle and cracks easily in arctic temperatures. The M700 time fuse is packaged in 50-foot coils, two coils per package, five packages per sealed container, and eight containers (4,000 feet) per wooden box (30 1/8 by 15 1/8 by 14 7/8 inches). The total package weighs 94 pounds.

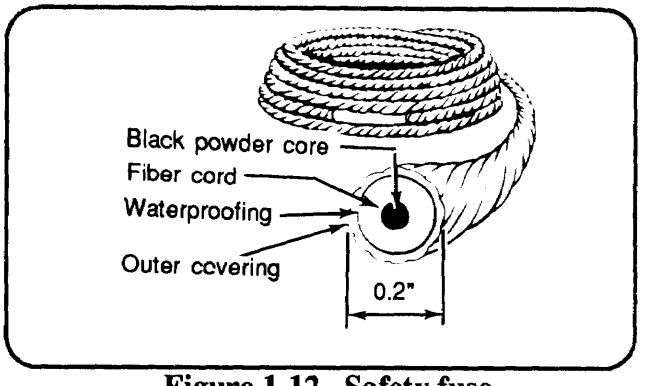


Figure 1-12. Safety fuse

b. *Safety Fuse.* Safety fuse consists of black powder tightly wrapped with several layers of fiber and waterproofing material. The outside covering becomes brittle and cracks easily in arctic temperatures. The burning rate may vary for the same or different rolls (30 to 45 seconds per foot) under different atmospheric and climatic conditions. This fuse may be any color, but orange is the most common (Figure 1-12). Test each roll in the area where the charge will be placed (paragraph 2-lb(l), page 2-2). Since safety fuse burns significantly faster underwater, test it underwater before preparing an underwater charge. Safety fuse is packaged in 50-foot coils, two coils per package, and 30 packages (3,000 feet) per wooden box (24¾ by 15¾ by 12 ½ inches). The total package weighs 93.6 pounds.

1-17. Detonating Cord.

a. *Characteristics. The* American, British, Canadian, and Australian (ABCA) Standardization Program recognizes this Type 1 detonating cord as the standard detonating cord. Detonating cord (Figure 1-13) consists of a core of high explosive (6.4 pounds of PETN per 1,000 feet) wrapped in a reinforced and waterproof olive-drab plastic coating. This detonating cord is approximately 0.2 inches in diameter, weighs approximately 18 pounds per 1,000 feet, and has a breaking strength of 175 pounds. Detonating cord is functional in the same temperature range as plastic explosive, although the cover becomes brittle at lower temperatures. Moisture can penetrate the explosive filling to a maximum distance of 6 inches from any cut or break in the coating. Water-soaked detonating cord will detonate if there is a dry end to allow initiation. For this reason, cut off and discard the first 6 inches of any new or used detonating cord that nonelectric blasting caps are crimped to. Also, leave a 6-inch overhang when making connections or when priming charges.

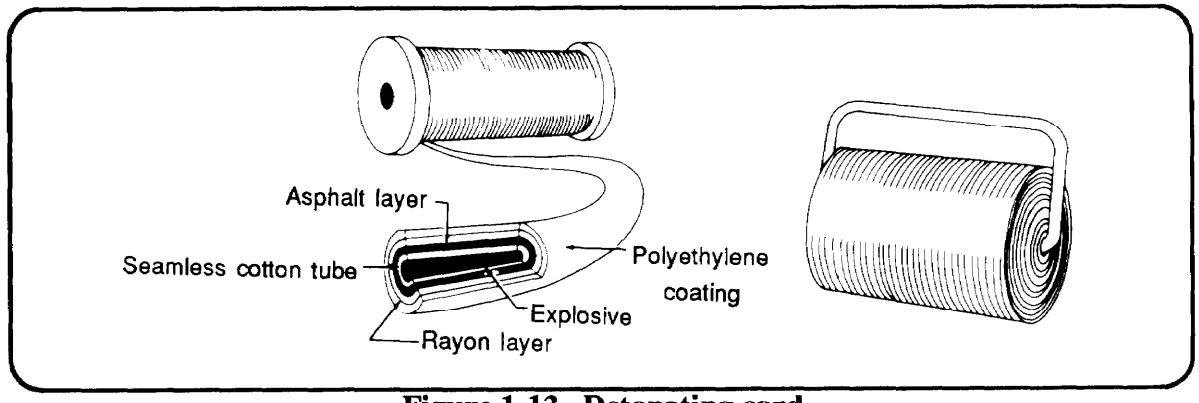


Figure 1-13. Detonating cord

b. *Use.* Use detonating cord to prime and detonate other explosive charges. When the detonating cord's explosive core is initiated by a blasting cap, the core will transmit the detonation wave to an unlimited number of explosive charges. Chapter 2 explains the use of detonating cord for these purposes.

c. Precautions. Seal the ends of detonating cord with a waterproof sealant when used to fire underwater charges or when charges are left in place several hours before firing. If left for no longer than 24 hours, a 6-inch overlap will protect the remainder of a line from moisture. Avoid kinks or sharp bends in priming, as they may interrupt or change the direction of detonation and cause misfires. Avoid unintended cross-overs of the detonating cord where no explosive connection is intended. To avoid internal cracking do not step on the detonating cord.

1-18. Blasting Caps. Blasting caps are for detonating high explosives. There are two types of blasting caps: electric and nonelectric. They are designed for insertion into cap wells and are also the detonating element in certain firing systems and devices. Blasting caps are rated in power, according to the size of their main charge. Commercial blasting caps are normally Number 6 or 8 and are for detonating the more sensitive explosives, such as commercial dynamite and tetryl. Special military blasting caps (M6 electric and M7 nonelectric) ensure positive detonation of the generally less sensitive military explosives. Their main charge is approximately double that of commercial Number 8 blasting caps. Never carry blasting caps loose or in uniform pockets where they are subject to shock. Separate blasting caps properly. Never store blasting caps with other explosives. Do not carry blasting caps and other explosives in the same truck except in an emergency (paragraph 6-11, page 6-10).

WARNING

Handle military and commercial blasting caps carefully, as both are extremely sensitive and may explode if handled improperly. Do not tamper with blasting caps. Protect them from shock and extreme heat.

a. *Electric Blasting Caps.* Use electric blasting caps when a source of electricity, such as a blasting machine or a battery, is available. Both military and commercial caps may be used. Military caps (Figure 1-14, page 1-6) operate instantaneously. Commercial caps may operate instantaneously or have a delay feature. The delay time of commercial caps for military applications ranges from 1 to 1.53 seconds. Electric caps have lead wires of various lengths. The most common lead length is 12 feet. Electric caps require 1.5 amperes of power to initiate. The standard-issue cap

is the M6 special electric blasting cap. TM 43-0001-38 gives additional information on blasting caps.

WARNING
Do not remove the short-circuiting shunt until ready to test the cap. Doing this prevents accidental initiation by static electricity. If the cap has no shunt, twist the lead's bare ends together with at least three 180-degree turns to provide a shunting action.

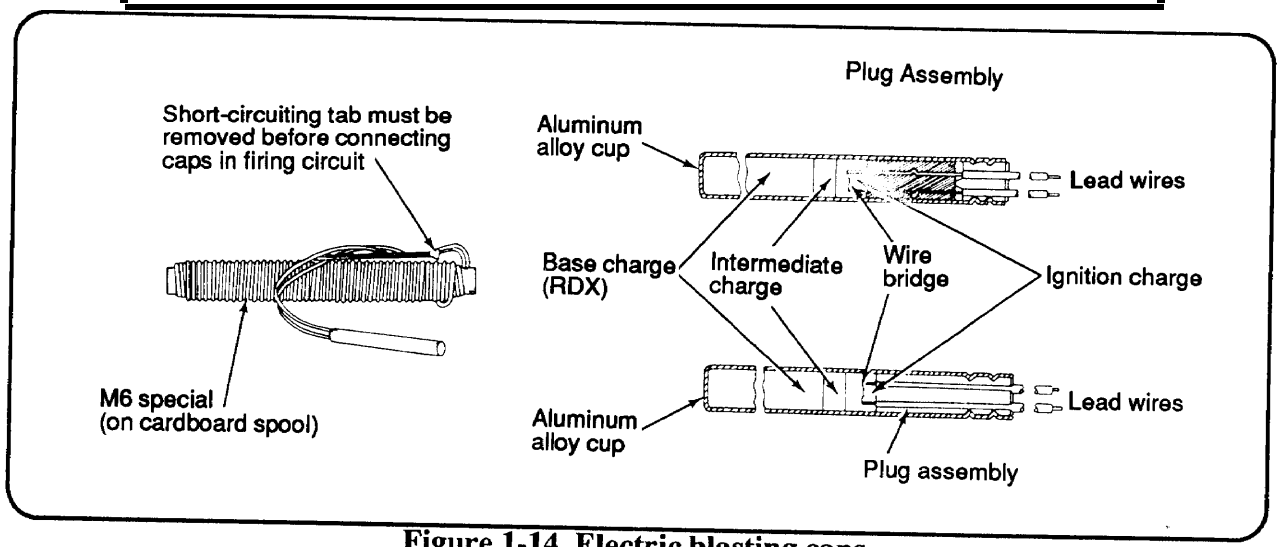


Figure 1-14. Electric blasting caps

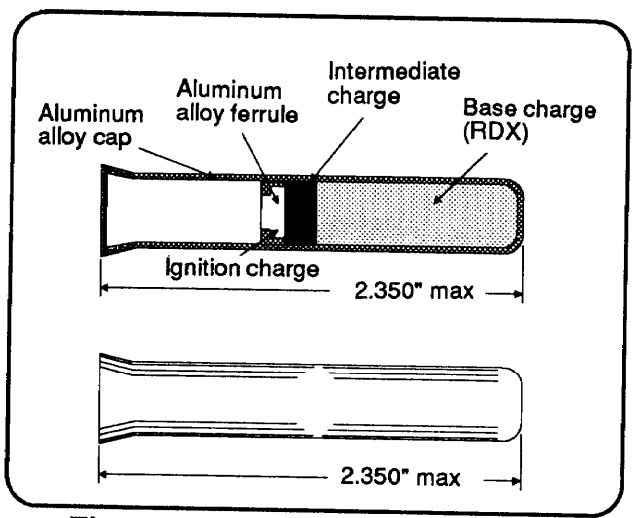


Figure 1-15. Nonelectric blasting cap

b. *Nonelectric Blasting Caps.* Initiate these caps with time-blasting fuse, a firing device, or detonating cord (Figure 1-15). Avoid using nonelectric blasting caps to prime underwater charges because the caps are hard to waterproof. If necessary, waterproof nonelectric blasting caps with a sealing compound. The M7 special nonelectric blasting cap is the standard issue. The open end of the M7 special nonelectric blasting cap is flared to allow easy insertion of the time fuse. TM 43-0001-38 gives additional information on blasting caps.

1-19. MlA4 Priming Adapter. The MIA4 priming adapter is a plastic, hexagonal-shaped device, threaded to fit threaded cap wells. The shoulder inside the threaded end will allow time blasting fuse and detonating cord to pass, but the shoulder is too small to pass a military blasting cap. To accommodate electric blasting caps, the adapter has a lengthwise slot that permits blasting cap lead wires to be quickly and easily installed in the adapter (Figure 1-16).

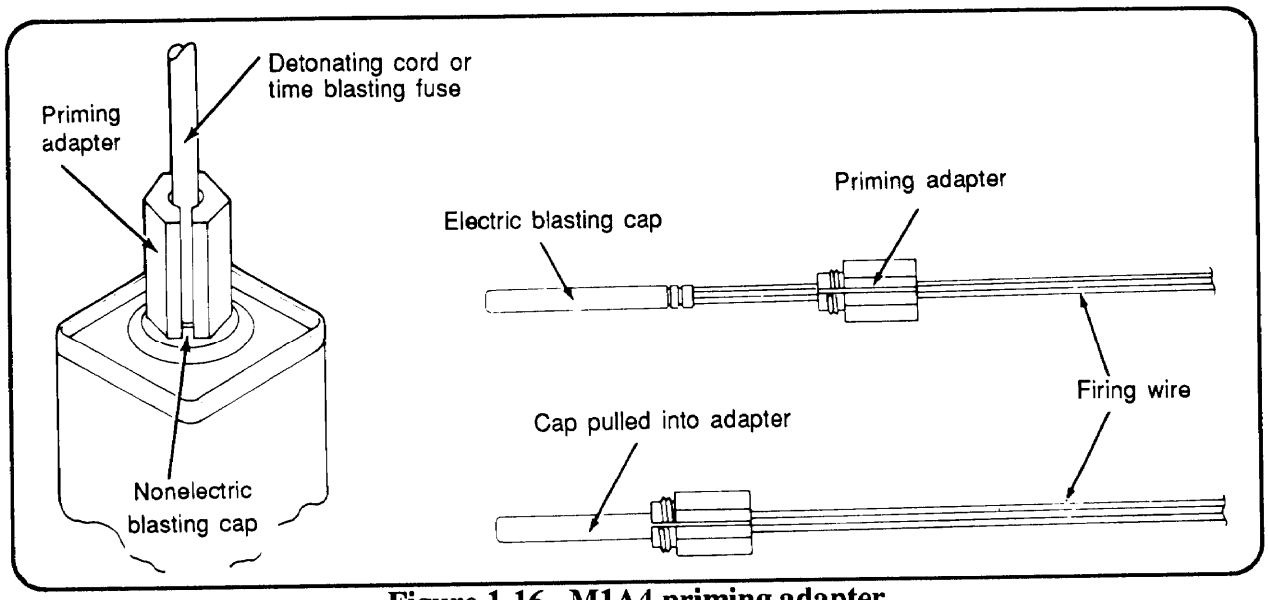


Figure 1-16. M1A4 priming adapter

1-20. M8 Blasting Cap Holder. The M8 blasting cap holder is a metal clip designed to attach a blasting cap to a sheet explosive (Figure 1-17). These clips are supplied with Ml18 sheet demolition charges and Ml86 roll demolition charges. The M8 blasting cap holder is also available as a separate-issue item in quantities of 4,000.

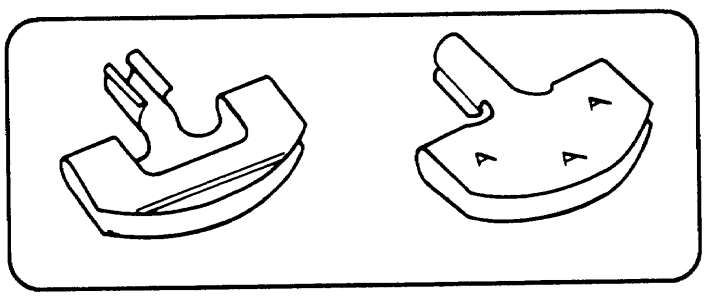


Figure 1-17. M8 blasting cap holder

1-21. Ml Detonating-Cord Clip. The Ml detonating-cord clip is a device for holding two strands of detonating cord together, either parallel or at right angles (Figure 1-18, diagram 1). Using these clips is faster and more efficient than using knots. Knots, if left for extended periods, may loosen and fail to function properly.

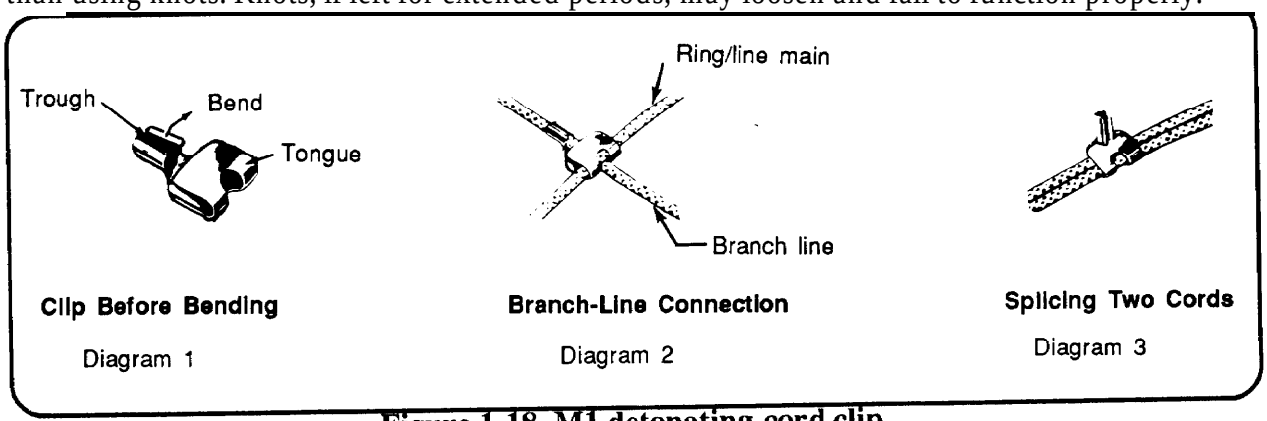


Figure 1-18. M1 detonating-cord clip

a. *Branch Lines.* Connect a detonating cord branch line by passing it through the trough of the Ml detonating cord clip and through the hole in the tongue of the clip. Next, place the line/ring main into the tongue of the clip so that it crosses over the branch line at a 90-degree angle and ensure

the crossover is held secure by the tongue; it may be necessary to bend or form the tongue while doing this. (Figure 1-18, diagram 2, page 1-17).

b. *Splices.* Splice the ends of detonating cords by first overlapping them approximately 12 inches. Then secure each loose end to the other cord by using a clip. Finally, bend the tongues of the clips firmly over both strands. Make the connection stronger by bending the trough end of the clip back over the tongue (Figure 1-18, diagram 3, page 1-17).

1-22. Ml Adhesive Paste. Ml adhesive paste is a sticky, putty-like substance that is used to attach charges to flat, overhead or vertical surfaces. Adhesive paste is useful for holding charges while tying them in place or, under some conditions, for holding without ties. This paste does not adhere satisfactorily to dirty, dusty, wet, or oily surfaces. Ml adhesive paste becomes useless when softened by water.

1-23. Pressure-Sensitive Adhesive Tape.

a. *Characteristics.* Pressure-sensitive tape is replacing Ml adhesive paste. Pressure-sensitive tape has better holding properties and is more easily and quickly applied. This tape is coated on both sides with pressure-sensitive adhesive and requires no solvent or heat to apply. It is available in 2-inch-wide rolls , 72 yards long.

b. *Use.* This tape is effective for holding charges to dry, clean wood, steel, or concrete.

c. *Limitations.* This tape does not adhere to dirty, wet, oily, or frozen surfaces.

1-24. Supplementary Adhesive for Demolition Charges.

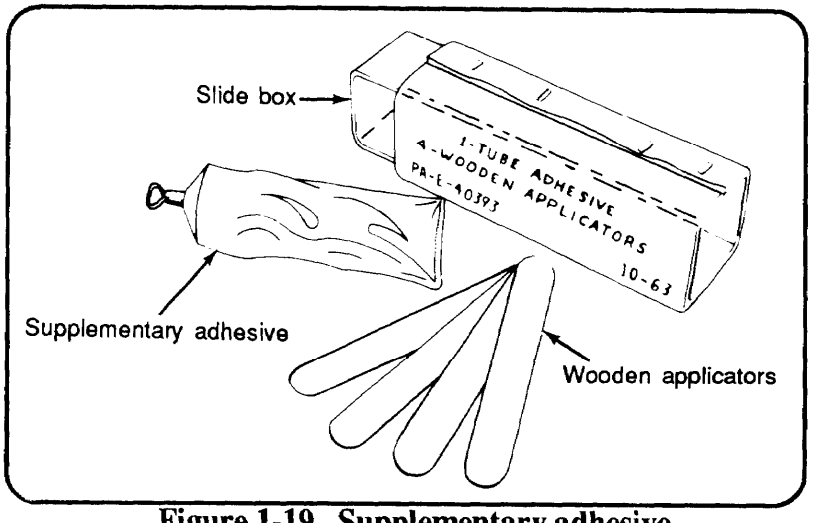


Figure 1-19. Supplementary adhesive

a. *Characteristics.* This adhesive is used to hold demolition charges when the target surface is below freezing, wet, or underwater. The adhesive comes in tubes packed in water-resistant, cardboard slide boxes, with wooden applicators (Figure 1-19).

b. *Use.* Apply the adhesive to the target surface and the demolition block with a wooden applicator and press the two together.

1-25. Waterproof Sealing Compound. This sealant is for waterproofing connections between time blasting fuses or detonating cords and nonelectric blasting caps. The sealing compound will not make a permanent waterproof seal. Since this sealant is not permanent, fire underwater demolitions as soon as possible after placing them.

1-26. M2 Cap Crimper. Use the M2 cap crimper (Figure 1-20) for squeezing the shell of a nonelectric blasting cap around a time blasting fuse, standard coupling base, or detonating cord.

Crimp the shell securely enough to keep the fuse, base, or cord from being pulled off, but not so tightly that it interferes with the operation of the initiating device. A stop on the handle helps to limit the amount of crimp applied. The M2 crimper forms a water-resistant groove completely around the blasting cap. Apply a sealing compound to the crimped end of the blasting cap to waterproof it. The rear portion of each jaw is shaped and sharpened for cutting fuses and detonating cords. One leg of the handle is pointed for punching cap wells in explosive materials. The other leg has a screwdriver end. Cap crimpers are made of a soft, nonsparking metal that conducts electricity. Do not use them as pliers because such use damages the crimping surface. Ensure crimp hole is round (not elongated) and the cutting jaws are not jagged. Keep the cutting jaws clean, and use them only for cutting fuses and detonating cords.

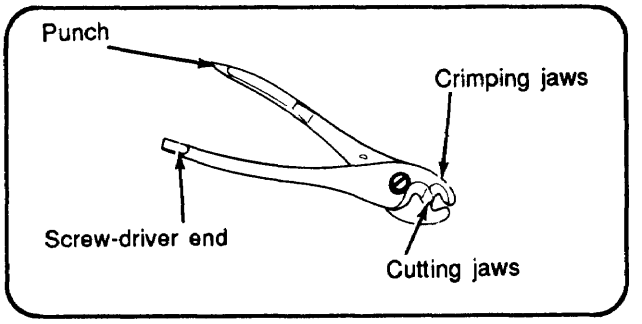


Figure 1-20. M2 cap crimper

1-27. M51 Blasting-Cap Test Set.

a. *Characteristics.* The test set is a self-contained unit with a magneto-type impulse generator, an indicator lamp, a handle to activate the generator, and two binding posts for attaching firing leads. The test set is waterproof and capable of operation at temperatures as low as -40 degrees Fahrenheit (Figure 1-21).

b. *Use.* Check the continuity of firing wire, blasting caps, and firing circuits by connecting the leads to the test-set binding posts and then depressing the handle sharply. If there is a continuous (intact) circuit, even one created by a short circuit, the indicator lamp will flash. When the circuit is open, the indicator lamp will not flash.

c. *Maintenance.* Handle the test set carefully and keep it dry to assure optimum use. Before using, ensure the test set is operating properly by using the following procedure:

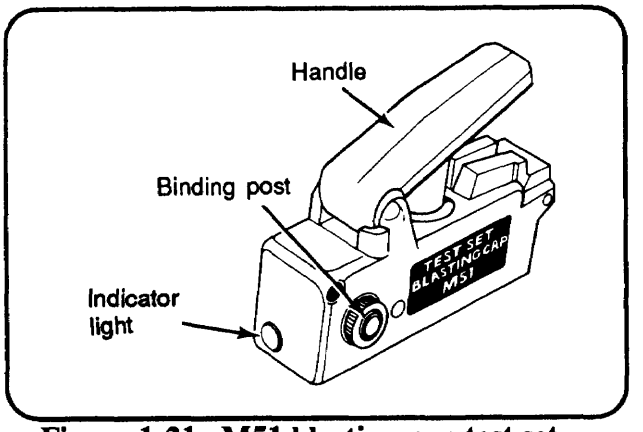


Figure 1-21. M51 blasting-cap test set

(1) Hold apiece of bare wire or the legs of the M2 crimpers between the binding posts.

(2) Depress the handle sharply while observing the indicator lamp. The indicator lamp should flash.

(3) Remove the bare wire or crimper legs from the binding posts.

(4) Depress the handle sharply while observing the indicator lamp. This time the indicator lamp should not flash.

(5) Perform both tests to ensure the test set is operating properly.

1-28. Blasting Machines. Blasting machines provide the electric impulse needed to initiate electric blasting-cap operations. When operated, the M32 and M34 models use an alternator and a capacitor to energize the circuit.

a. *M32 10-Cap Blasting Machine.* This small, lightweight blasting machine (Figure 1-22) produces adequate current to initiate 10 electrical caps connected in series using 500 feet of WD-l cable. To operate the machine, use the following procedure:

(1) Check the machine for proper operation. Release the blasting machine handle by rotating the retaining ring downward while pushing in on the handle. The handle will automatically spring outward from the body of the machine.

(2) Activate the machine by depressing the handle rapidly three or four times until the neon indicator lamp flashes. The lamp is located between the wire terminal posts and cannot be seen until it flashes, since it is covered by green plastic.

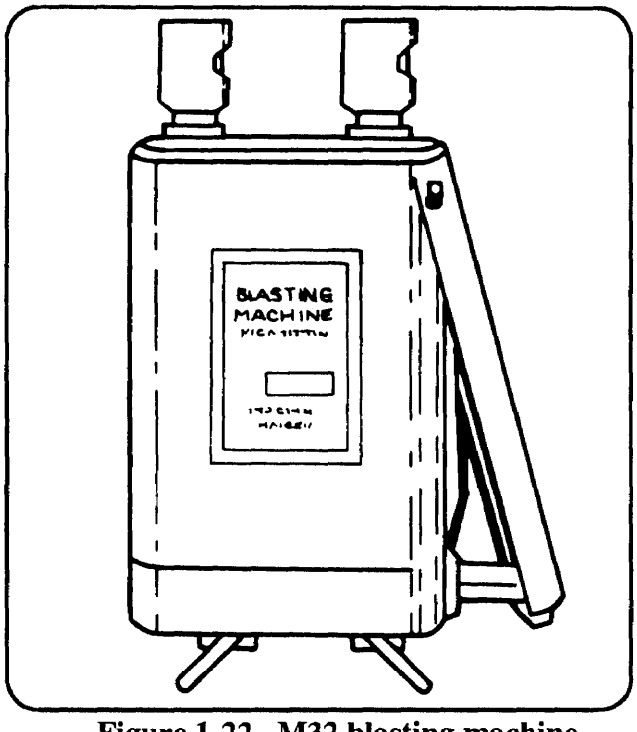


Figure 1-22. M32 blasting machine

(3) Insert the firing wire leads into the terminals by pushing down on each terminal post and inserting the leads into the metal jaws.

(4) Hold the machine upright (terminals up) in either hand, so the plunger end of the handle rests in the base of the palm and the fingers grasp the machine's body. Be sure to hold the machine correctly, as the handles are easily broken.

(5) Squeeze the handgrip sharply several times until the charge fires. Normally, no more than three or four strokes are required.

b. *M34 50-Cap Blasting Machine.* This small, lightweight machine produces adequate current to initiate 50 electrical caps connected in a series. It looks like the M32 blasting machine (Figure 1-22) except for a black band around the base and a steel-reinforced actuating handle. Test and operate the M34 in the same manner as the M32.

1-29. Firing Wire and Reels.

a. *Types of Firing Wire.* Wire for firing electric charges is available in 200- and 500-foot coils. The two-conductor AWG Number 18 is a plastic-covered or rubber-covered wire available in 500-foot rolls. This wire is wound on an RL39A reel unit. The single-conductor. AWG Number 20 annunciator wire is available in 200-foot coils and is used to make connections between blasting caps and firing wire. The WD- l/TT communication wire will also work, but it requires a greater power source if more than 500 feet are used (blasting machines will not initiate the full-rated number

of caps connected with more than 500 feet of WD-l/TT wire). As a rule of thumb, use 10 less caps than the machine's rating for each additional 1,000 feet of WD-1/TT wire employed.

b. *Reel.* The RL39A reel, with spool, accommodates 500 feet of wire. The reel has a handle assembly, a crank, an axle, and two carrying straps (Figure 1-23). The fixed end of the wire extends from the spool through a hole in the side of the drum and fastens to two brass thumb-out terminals. The carrying handles are two U-shaped steel rods. A loop at each end encircles a bearing assembly to accommodate the axle. The crank is riveted to one end of the axle, and a cotter pin holds the axle in place on the opposite end.

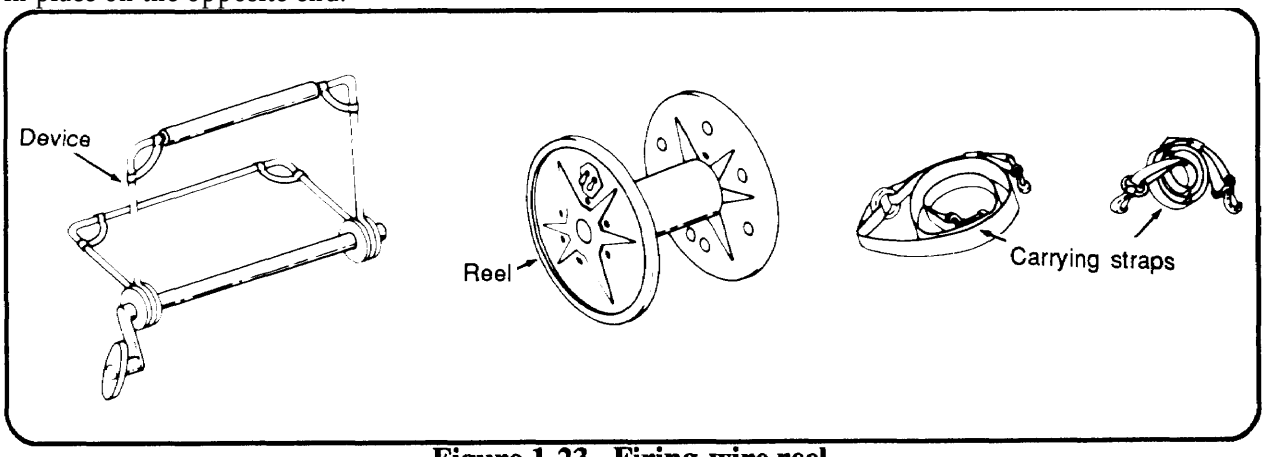


Figure 1-23. Firing-wire reel

1-30. Firing Devices and Other Accessory Equipment

a. *M60 Weatherproof Fuze Igniter.* This device is for igniting timed blasting fuse in all weather conditions, even underwater, if properly waterproofed. Insert the fuse through a rubber sealing grommet and into a split collet. This procedure secures the fuse when the end capon the igniter is tightened (Figure 1-24, page 1-22). Pulling the pull ring releases the striker assembly, allowing the firing pin to initiate the primer, igniting the fuse. Chapter 2 (page 2-4) gives detailed operating instructions for the M60 igniter.

b. *Demolition Equipment Set.* This set (Electric and Nonelectric Explosive Initiating Demolition Equipment Set) is an assembly of tools necessary for performing demolition operations (Table 1-4, page 1-22).

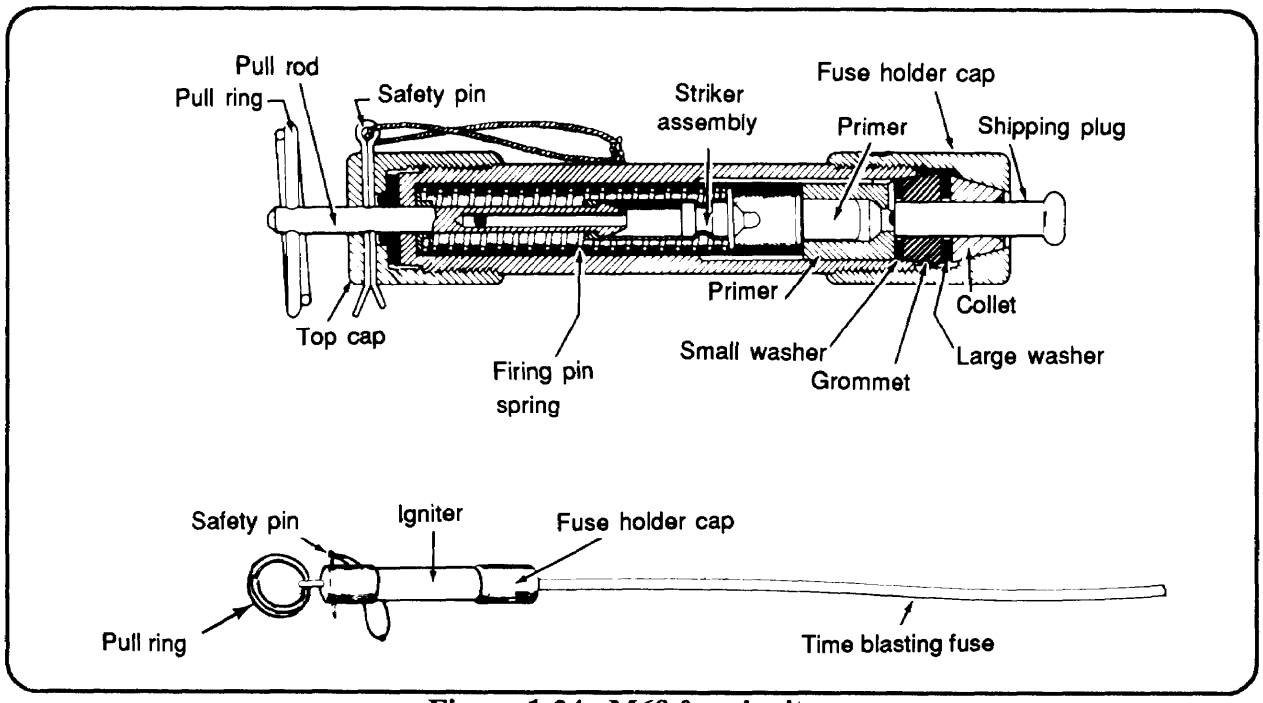


Figure 1-24. M60 fuze igniter

Table 1-4. Demolition equipment set

Quantity	Nomenclature	Quantity	Nomenclature
3	Bag, Demolition Equipment	1	Machine, Blasting, M34
5	Box, Blasting Cap, Plastic, 10-Cap	2	Pliers, Lineman's, w/ Side Cutter, 8-Inch
1	Chest, Demo, Engr Plt, M1931	1	Pliers, Diagonal-Cutting, 6-Inch
4	Crimper, Blasting Cap, M2	4	Reel, Cable
2	Knife, Pocket, w/ Can Opener and Punch	1	Machine, Cable-Reeling, Manual
2	Knife, Pocket, w/ Screwdriver and Wire Scraper	1	Set, Blasting-Cap Test, M51
1	Shears, Metal-Cutting, Manual, 8-Inch	**NOTE:** The individual items listed in this set are available separately.	
2	Tape, Measuring, Steel, Millimeters and Inches		
1	Tape, Measuring, Plastic-Coated, 100-Foot		

Chapter 2
Initiating Sets, Priming, and Firing Systems

Section I. Initiating Sets

WARNING
Refer to the safety procedures in Chapter 6 before undertaking any demolitions mission.

2-1. Nonelectric Initiation Sets.

a. *Components Assembly.* A nonelectric system uses a nonelectric blasting cap as the initiator. The initiation set consists of a fuse igniter (produces flame that lights the time fuse), the time blasting fuse (transmits the flame that fires the blasting cap), and a nonelectric blasting cap (provides shock adequate to detonate the explosive) (Figure 2-1). When combined with detonating cord, a single initiation set can fire multiple charges.

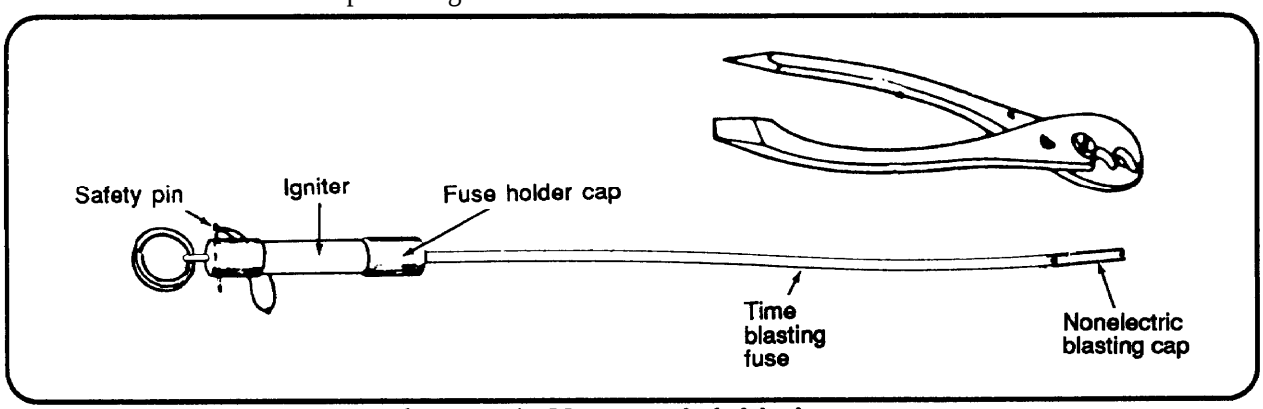


Figure 2-1. Nonelectric initiation set

b. *Preparation Sequence.* Preparing demolitions for nonelectric initiation follows a specified process. This process includes—

- Step 1. Checking the time fuse.
- Step 2. Preparing the time fuse.
- Step 3. Attaching the fuse igniter.
- Step 4. Installing the primer adapter.
- Step 5. Placing the blasting cap.

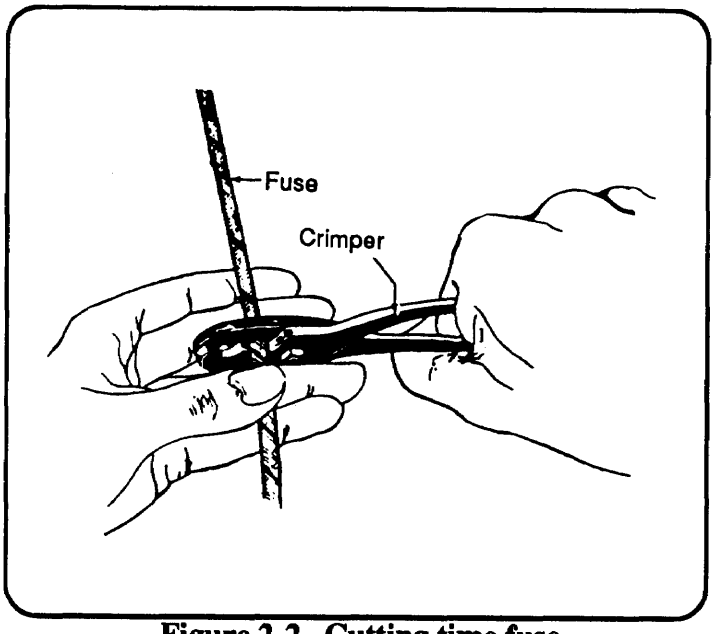


Figure 2-2. Cutting time fuse

(1) Checking Time Fuse. Test every coil of fuse, or remnant of a coil, using the burning-rate test prior to use. One test per day per coil is sufficient. Never use the first and last 6 inches of a coil because moisture may have penetrated the coil to this length. Using an M2 crimper, cut and discard a 6-inch length from the free end of the fuse (Figure 2-2). Cut off and use a 3-foot length of the fuse to check the burning rate. Ignite the fuse and note the time it takes for the fuse to burn. Compute the burning rate per foot by dividing the bum time in seconds by the length in feet. If the test bum does not fall within ± 5 seconds of a 40-second-per-foot burn rate, perform another test to verify your results.

WARNING
Test burn a 3-foot length of time blasting fuse to determine the exact rate prior to use.

(2) Preparing Time Fuse. Cut the fuse long enough to allow the person detonating the charge to reach safety (walking at a normal pace) before the explosion. Walk and time this distance prior to cutting the fuse to length. The formula for determining the length of time fuse required is—

$$\frac{\textit{Time Required (min)} \times 60\ \textit{(sec/min)}}{\textit{Burning Rate (sec/ft)}} = \textit{Fuse Length (ft)} \qquad \textbf{(2-1)}$$

Make your cut squarely across the fuse. Do not cut the fuse too far in advance, since the fuse may absorb moisture into the open ends. Do not allow the time fuse to bend sharply, as you may crack the black powder core, resulting in a misfire.

(3) Attaching Fuze Igniter. To attach an M60 weatherproof fuze igniter, unscrew the fuse holder cap two or three turns, but do not remove the cap. Press the shipping plug into the igniter to release the split collet (Figure 1-24, page 1-22). Rotate and remove the plug from the igniter. Insert the free end of the time fuse as far as possible into the space left by the removed shipping plug. Sufficiently tighten the holder cap to hold the fuse and weatherproof the joint.

(4) Installing Priming Adapter. If you use a priming adapter to hold a nonelectric blasting cap, place the time fuse through the adapter before installing (crimping) the blasting cap onto the fuse. Ensure the adapter threads are pointing to the end of the time fuse that will receive the blasting cap.

(5) Preparing Blasting Caps.

(a) Inspection. Hold the cap between the thumb and ring finger of one hand, with the forefinger of the same hand on the closed end of the blasting cap. Inspect the blasting cap by looking into the open end. You should see a yellow-colored ignition charge. If dirt or any foreign matter is present, do the following:

- Aim the open end of the cap at the palm of the second hand.
- Gently bump the wrist of the cap-holding hand against the wrist of the other hand.
- If the foreign matter does not dislodge, do not use the cap.

(b) Placing and crimping. Use this procedure for installing blasting caps onto fuse. Using this procedure will allow accurate crimping, even in darkness, because finger placement guides the crimpers to the open end of the blasting cap. Use the following procedures to attach a nonelectric blasting cap onto time fuse:

- Hold the time blasting fuse vertically with the square-cut end up, and slip the blasting cap gently down over the fuse so the flash charge in the cap touches the fuse.

WARNING

If the charge in the cap is not in contact with the fuse, the fuse may not ignite the cap (misfire). Never force a time fuse into a blasting cap, for example, by twisting or any other method. If the fuse end is flat or too large to enter the blasting cap freely, roll the fuse between the thumb and fingers until it will freely enter the cap. A rough, jagged-cut fuse inserted in a blasting cap can cause a misfire. If the cutting jaws of the M2 crimper are unserviceable, use a sharp knife to cut the fuse. When using a knife to cut fuse squarely, cut the fuse against a solid, nonsparking surface such as wood.

- While applying slight pressure with the forefinger on the closed end of the cap, grasp the fuse with the thumb and ring finger.
- Using the opposite hand, grasp the crimpers. Place the crimping jaws around the cap at a point 1/8 to ¼ inch from the open end. The thumb and ring finger that hold the fuse will be below the crimpers. Rest the second finger of the hand holding the fuse on top of the crimpers to prevent the crimpers from sliding up the cap (Figure 2-3, page 2-4).

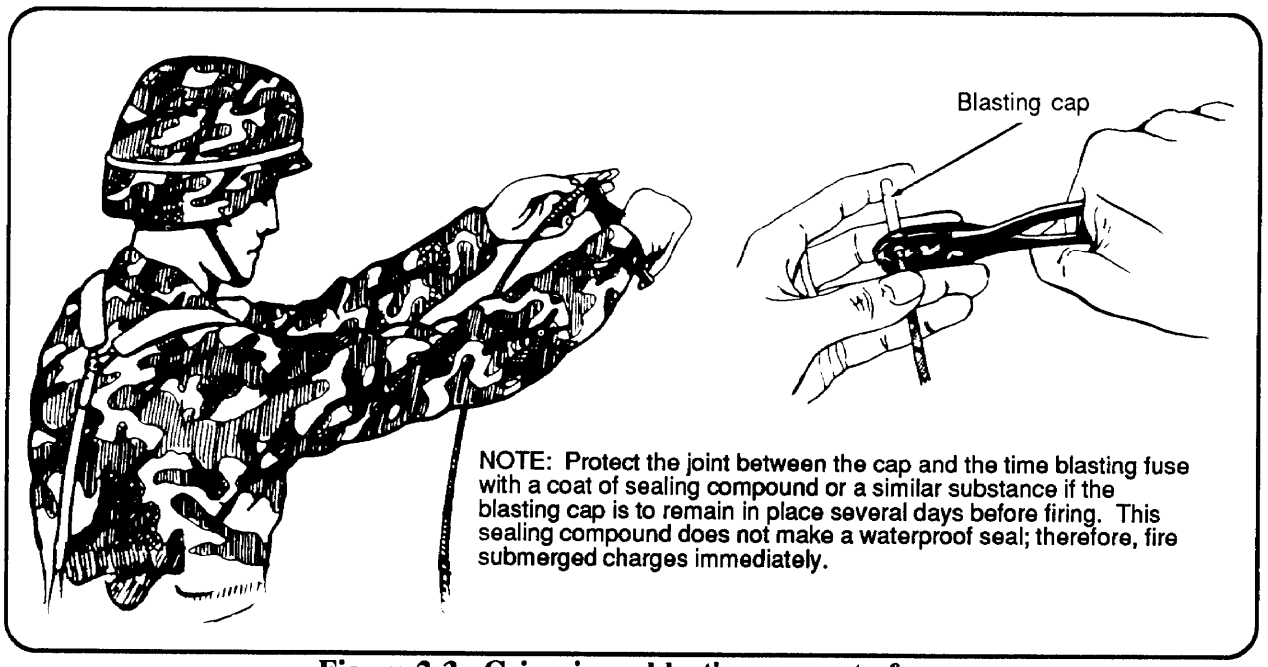

Blasting cap
NOTE: Protect the joint between the cap and the time blasting fuse with a coat of sealing compound or a similar substance if the blasting cap is to remain in place several days before firing. This sealing compound does not make a waterproof seal; therefore, fire submerged charges immediately.

Figure 2-3. Crimping a blasting cap onto fuse

- Extend both arms straight out while rotating the hands so that the closed end of the blasting cap is pointing away from the body and from other personnel.
- Crimp the blasting cap by firmly squeezing the M2 crimper handles together, maintaining eye contact with the blasting cap. Inspect the crimp after you have finished. Ensure that the fuse and cap are properly joined by gently trying to pull them apart

NOTE: Attach the M60 fuze igniter to the time fuse before crimping a blasting cap to the opposite end. Do not remove the safety pin until you are ready to detonate the charge.

WARNING
Do not crimp too close to the explosive end of the blasting cap; doing this may cause the cap to detonate.
Point the cap out and away from the body during crimping.

NOTE: If the cap is to remain in place several days before firing, protect the joint between the cap and the timed blasting fuse with a coat of sealing compound or similar substance. This sealing compound will not make a waterproof seal; therefore, fire submerged charges immediately.

NOTE: See paragraph 6-8 (page 6-8) for procedures on handling nonelectric misfires.

c. *Fuse Initiation.* To fire the assembly, hold the M60 igniter in one hand and remove the safety pin with the other. Grasp the pull ring and give it a quick, hard pull. In the event of a misfire, reset the M60 by pushing the plunger all the way in, rotate it left and right, and attempt to fire as before.

WARNING
Water can enter through the vent hole in the pull rod when attempting to reset the igniter under water.
This will prevent the fuse igniter from working after resetting.

NOTE: If a fuze igniter is not available, light the time blasting fuse with a match. Split the fuse at the end (Figure 2-4) and place the head of an unlit match in the powder train. Light the inserted match head with a flaming match, or rub the abrasive on the match box against it. It may be necessary to use two match heads during windy conditions.

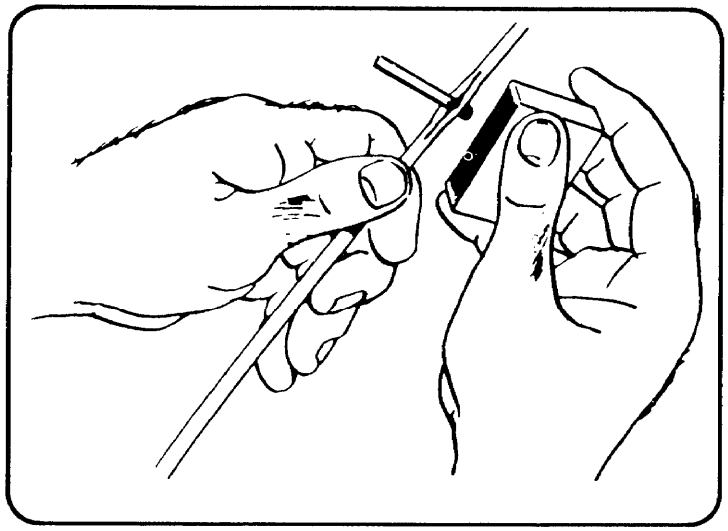


Figure 2-4. Lighting time fuse with a match

2-2. Electric Initiation Sets.

a. *Preparation Sequence.* Use the process below to make an electric initiation set. This process includes—

- Testing and maintaining control of the blasting machine.
- Testing the M51 blasting-cap test set.
- Testing the firing wire on the reel, shunted and unshunted.
- Laying out the firing wire completely off the reel.
- Retesting the firing wire, shunted and unshunted.
- Testing the blasting caps.
- Connecting the series circuit.
- Connecting the firing wire.
- Testing the entire circuit.
- Priming the charges.

b. *Components Assembly.* An electric system uses an electric blasting cap as the explosion initiator. The initiation set consists of an electric blasting cap, the firing wire, and a blasting machine (Figure 2-5). An electric impulse (usually provided by a blasting machine) travels through the firing wires and blasting cap leads, detonating the blasting cap which initiates the explosion. Radio waves can also detonate electric blasting caps. Therefore, observe the minimum safe distances listed in Chapter 6 (page 6-5) at all times. When combined with detonating cord, a single initiation set can fire multiple charges. TM 9-1375-213-34 provides detailed information about electric blasting equipment.

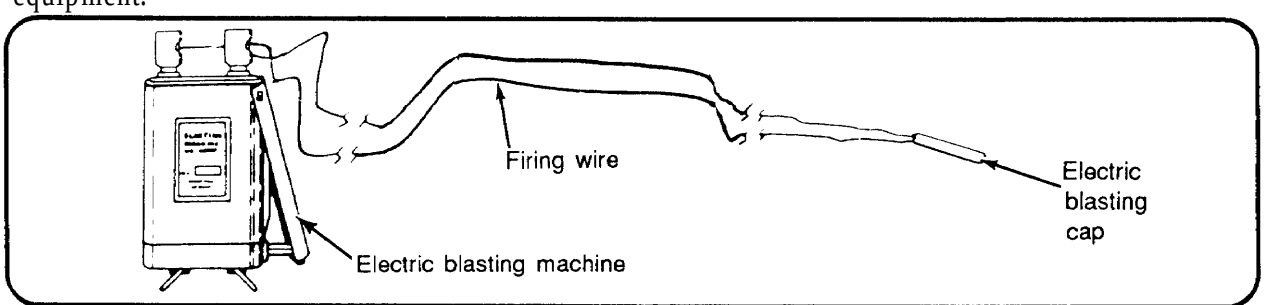


Figure 2-5. Electric initiation set

Always follow the procedure below when preparing an electric initiation set:

(1) Testing and Maintaining Control of Blasting Machine.

(a) Test the blasting machine to ensure it is operating properly (paragraph 1-28, page 1-20).

(b) Control access to all blasting machines. The supervisor is responsible for controlling all blasting machines.

(2) Testing M51 Blasting-Cap Test Set.

(a) Check the M51 test set to ensure it is operating properly (paragraph 1-27, page 1-19).

(b) Perform both the open- and short-circuit tests.

(3) Testing Firing Wire on the Reel.

(a) Separate the firing wire leads at both ends and connect the leads at one end to the posts of the MS 1 test set. Squeeze-tie test-set handle. The indicator lamp should NOT flash. If it does, the lamp's flash indicates a short circuit in the firing wire (Figure 2-6).

(b) Shunt the wires atone end and connect the leads from the other end to the posts of the M51 test set. Squeeze the test-set handle. The indicator lamp should flash. If it does not, the lamp's failure to light indicates a break in the firing wire (Figure 2-6).

NOTE: Use at least three 180-degree turns to shunt wires.

(c) Shunt both ends of the firing wire after testing.

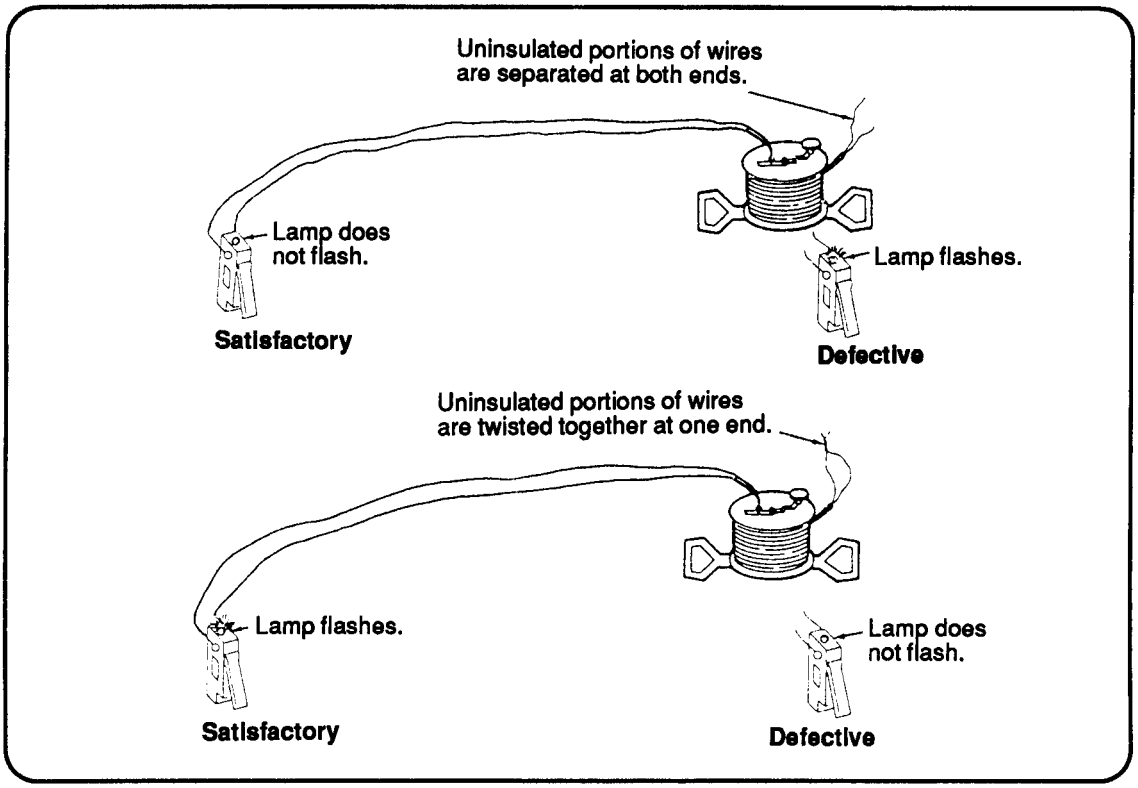


Figure 2-6. Testing firing wire on the reel

(4) Laying Out Firing Wire.

(a) After locating a firing position a safe distance away from the charges (paragraph 6-7, page 6-6), lay out the firing wire between the charges and the firing position. More than one reel of wire may be necessary.

(b) Do not allow vehicles to drive over or personnel to walk on firing wire. Always bury firing wire or lay it flat on the ground.

(c) Keep the firing wire as short as possible. Avoid creating any loops in the wire (lay it in as straight a line as possible). Cut the wire to length. Do not connect it to a blasting machine through the unused portion of wire on the reel.

(5) Retesting Firing Wire.

(a) Peform the open- and short-circuit tests again. The process of unreeling the wire may have separated broken wires not found when the wire was tested on the reel.

(b) Continually guard the firing position from this point on. Do this to ensure that no one tampers with the wires or fires the charges prematurely.

(c) Use hand signals to indicate the test results. Hand signals are necessary because of the distance involved between the charges and the firing position. The man testing the wire also can give these signals directly to the soldier at the opposite end of the wire or, if they cannot see each other, through intermediate positions or over the radio. The tester indicates to his assistant that he wants the far end of the firing wire unshunted by extending both arms straight out at shoulder height. After unshunting the firing wire, the assistant at the far end of the wire repeats the signal, indicating to the tester that his end is unshunted. When the tester wants the far end of the firing wire shunted, he signals to his assistant by clasping his hands together and extending his arms over his head, elbows bent, forming a diamond shape. After shunting the firing wire, the assistant repeats the signal, indicating to the tester that his wire is shunted.

(d) Shunt both ends of the firing wire after the tests are complete.

(6) Testing Electric Blasting Cap.

(a) Remove the cap from its spool. Place the cap in the palm of your hand, lead wires passing between your thumb and index finger.

(b) Wrap the wire around the palm of your hand twice. Doing this prevents tension on the wires in the cap and prevents the cap from being dropped.

(c) Grasp the wire spool with your free hand and unreel the wire, letting the wire pass between your fingers as you turn the spool. Completely unreel the cap wires from the cardboard spool. Avoid allowing the wires to slip offends of the cardboard spool, since this will cause excessive twists and kinks in the wires and prevent the wires from separating properly.

(d) Place the blasting cap under a sandbag or helmet while extending the wires to their full length.

(e) Test blasting caps away from all other personnel. Keep your back to the blasting cap when testing it.

(f) Remove the short-circuit shunt from the lead wires.

(g) Hold or attach one lead wire to one of the M51's binding posts. Hold or attach the second lead wire to the other binding post and squeeze the test-set handle. The blasting cap is good if the indicator lamp flashes. If the lamp does not flash, the cap is defective; do not use it.

(h) Always keep the cap wires shunted when not testing them.

(7) Connecting a Series Circuit. When two or more blasting caps are required for a demolition operation. you may use one of the series circuits illustrated in Figure 2-7.

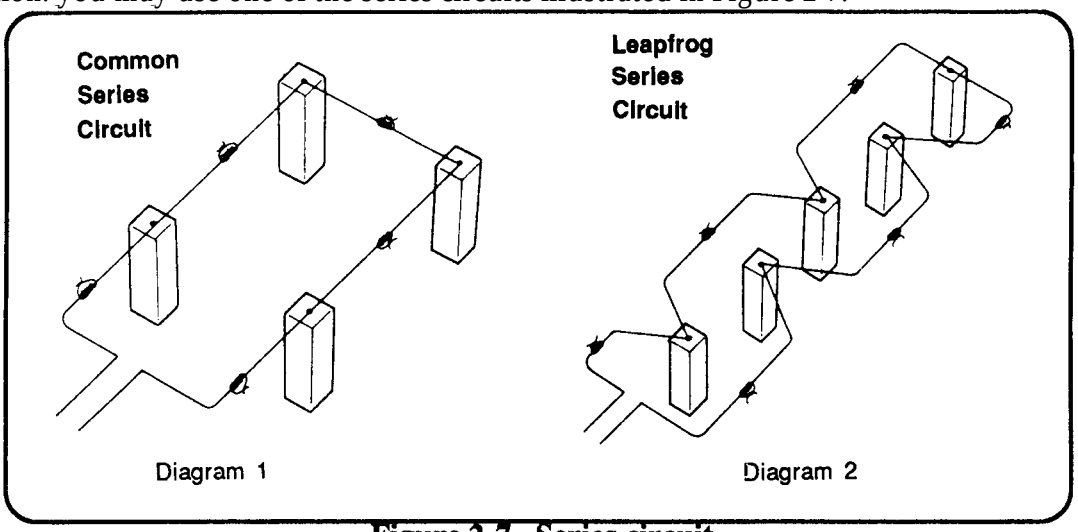


Figure 2-7. Series circuit

Use the following procedure:

(a) Test all blasting caps (paragraph 2-2b(6), page 2-7) separately before connecting them in a circuit.

(b) Join blasting cap wires together using the Western Union pigtail splice (Figure 2-8). Protect all joints in the circuit with electrical insulation tape. Do not use the cardboard spool that comes with the blasting cap to insulate these connections.

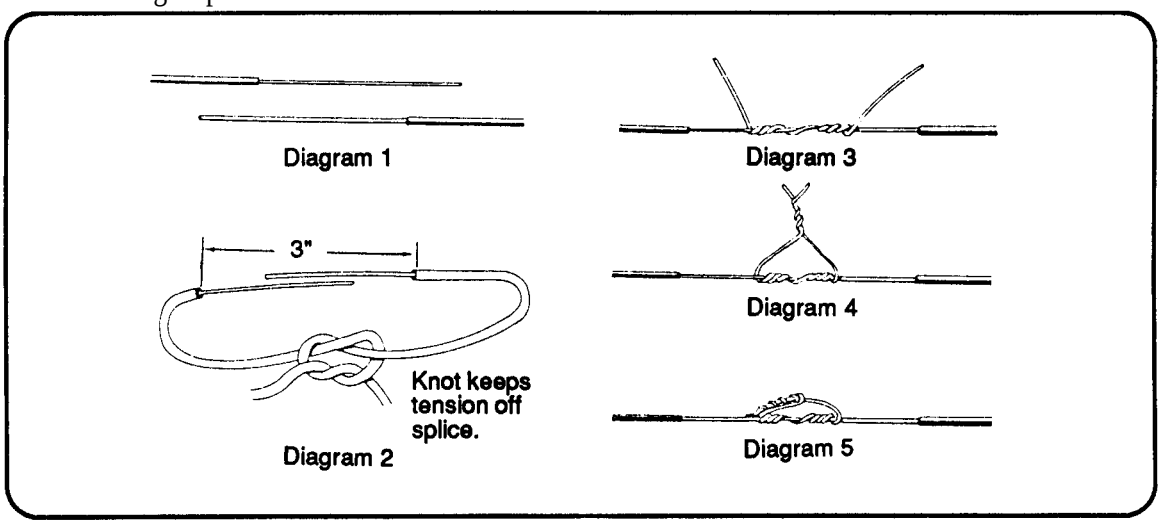


Figure 2-8. Western Union pigtail splice

(c) Test the entire circuit. After the series is completed, connect the two free blasting cap wires to the M51 test set. The indicator lamp should flash to indicate a good circuit. If the lamp does not flash, check your connections and blasting caps again.

(d) After testing the cap circuit, shunt the two free blasting cap wires until you are ready to connect them to the firing wire.

(8) Connecting the Firing Wire.

(a) Connect the free leads of blasting caps to the firing wire before priming the charges or taping a blasting cap to a detonating-cord ring main.

(b) Use a Western Union pigtail splice to connect the firing wire to the blasting cap wires.

(c) Insulate the connections with tape. Never use the cardboard spool that comes with the blasting cap to insulate this connection. The firing wire is likely to break when bent to fit into the spool.

(9) Testing the Entire Firing Circuit. Before priming the charges or connecting blasting caps to ring mains, test the circuit from the firing point. Use the following procedure:

(a) Ensure the blasting caps are under protective sandbags while performing this test.

(b) Connect the ends of the firing wire to the M51 test set. Squeeze the firing handle. The indicator lamp should flash, indicating a proper circuit.

(c) Shunt the ends of the firing wire.

WARNING
Do not prime charges or connect electric blasting caps to detonating cord until all other steps of the preparation sequence have been completed.

(10) Priming the Charges. Prime the charges and return to the firing point. This is the last step prior to actually returning to the firing point and firing the circuit.

WARNING
Prime charges when there is a minimum of personnel on site.

c. *Circuit Initiation.* At this point the initiation set is complete. Do not connect the blasting machine until all personnel are accounted for and the charge is ready to fire. When all personnel are clear, install the blasting machine and initiate the demolition. Chapter 6 (page 6-9) covers procedures for electric misfires.

d. *Splicing Electric Wires.*

(1) Preparation. Strip the insulating material from the end of insulated wires before splicing. Remove approximately 1 ½ inches of insulation from the end of each wire (Figure 2-8, diagram 1). Also remove any coating on the wire, such as enamel, by carefully scraping the wire with the back of a knife blade or other suitable tool. Do not nick, cut, or weaken the bare wire. Twist multiple-strand wires lightly after scraping.

(2) Method. Use the Western Union pigtail splice (Figure 2-8, page 2-8) to splice two wires. Splice two pairs of wires in the same way as the two-wire splice (Figure 2-9). Use the following procedure:

(a) Protect the splices from tension damage by tying the ends in an overhand or square knot (tension knot), allowing sufficient length for each splice (Figure 2-8, diagram 2, page 2-8).

(b) Make three wraps with each wire (Figure 2-8, diagram 3, page 2-8).

(c) Twist the ends together with three turns (Figure 2-8, diagram 4, page 2-8).

(d) Flatten the splice, but not so far that the wire crimps itself and breaks (Figure 2-8, diagram 5, page 2-8).

(3) Precautions. A short circuit may occur at a splice if you do not practice some caution. For example, when you splice pairs of wires, stagger the splices and place a tie between them (Figure 2-9, diagram 1). Another method of preventing a short circuit in a splice is using the alternate method (Figure 2-9, diagram 2). In the alternate method, separate the splices rather than stagger them. Insulate the splices from the ground or other conductors by wrapping them with friction tape or other electric insulating tape. Always insulate splices.

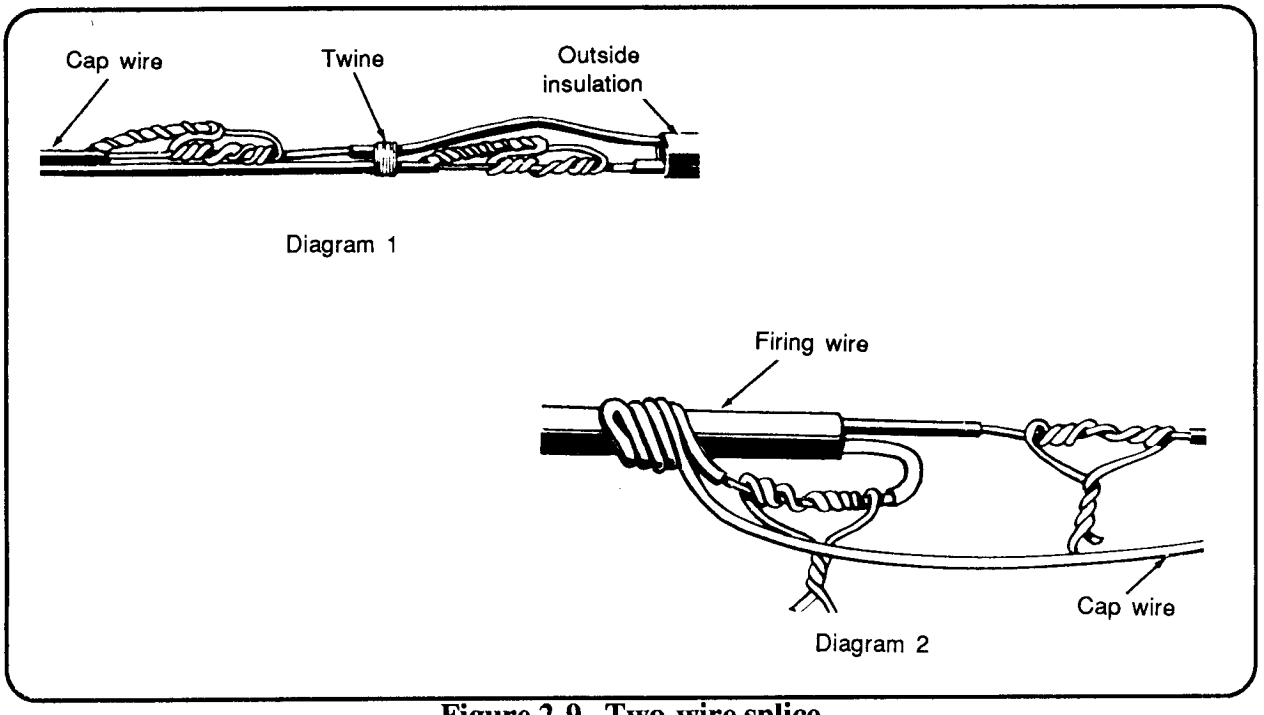


Figure 2-9. Two-wire splice

e. *Series Circuits.*

(1) Common. Use this circuit to connect two or more electric blasting caps to a single blasting machine (Figure 2-7, diagram 1, page 2-8). Prepare a common series circuit by connecting one blasting cap to another until only two end wires are free. Shunt the two end wires until you are ready to proceed with the next step. Connect the free ends of the cap lead wires to the ends of the firing wire. Use connecting wires (usually annunciator wire) when the distance between blasting caps is greater than the length of the usual cap lead wires.

(2) Leapfrog. The leapfrog method of connecting caps in a series is useful for firing any long line of charges (Figure 2-7, diagram 2, page 2-8). This method is performed by starting at one end of a row of charges and priming alternate charges to the opposite end and then priming the remaining charges on the return leg of the series. This method eliminates the necessity for a long return lead from the far end of the line of charges. Appendix E has additional information on series circuits. There is seldom a need for this type of circuit, since detonating cord, when combined with a single blasting cap, will fire multiple charges.

Section II. Priming Systems

2-3. Methods. The three methods of priming charges are nonelectric, electric, and detonating-cord. Nonelectric and electric priming involves directly inserting blasting caps into the charges. Use the direct-insertion method only when employing shaped charges. Detonating-cord priming is the prefered method for priming all other charges since it involves fewer blasting caps, makes priming and misfire investigation safer, and allows charges to be primed at State of Readiness 1 (safe) when in place on a reserved demolition.

NOTE: You can crimp nonelectric blasting caps to detonating cord as well as time fuse. This capability permits simultaneous firing of multiple charges primed with a blasting cap.

2-4. Priming TNT Demolition Blocks.

a. *Nonelectric.* TNT blocks have threaded cap wells. Use priming adapters, if available, to secure nonelectric blasting caps and timed blasting fuses to TNT blocks with threaded cap wells (Figure 2-10). When priming adapters are not available, prime TNT blocks with threaded cap wells as follows:

(1) Wrap a string tightly around the block of TNT and tie it securely, leaving approximately 6 inches of loose string on each end (Figure 2-11).

(2) Insert a blasting cap with the fuse attached into the cap well.

(3) Tie the loose ends of the string around the fuse to prevent the blasting cap from being separated from the block. Adhesive tape can also effectively secure blasting caps in charges.

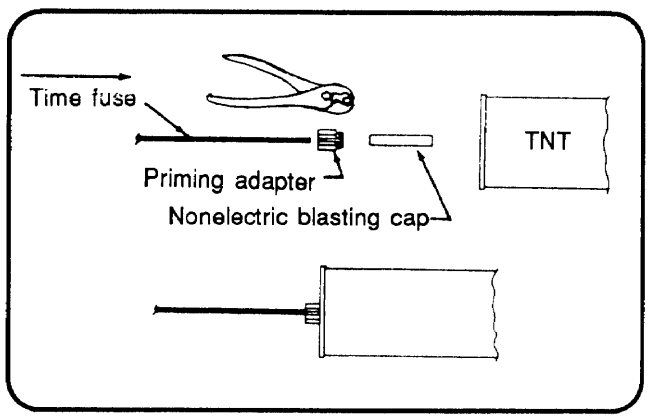


Figure 2-10. Nonelectric priming with adapter

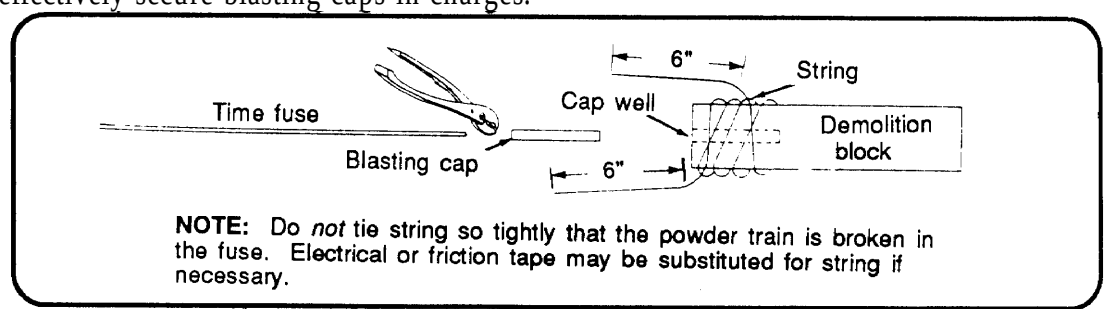

6"
String
Cap well
Time fuse
Demolition block
Blasting cap
6"
NOTE: Do *not* tie string so tightly that the powder train is broken in the fuse. Electrical or friction tape may be substituted for string if necessary.

Figure 2-11. Nonelectric priming without adapter

b. *Electric.*

(1) With Priming Adapter. Use the following procedure for priming TNT block, using the priming adapter:

(a) Prepare the electric initiation set before priming.

(b) Pass the lead wires through the slot of the adapter, and pull the cap into place in the adapter (Figure 2-12). Ensure the blasting cap protrudes from the threaded end of the adapter.

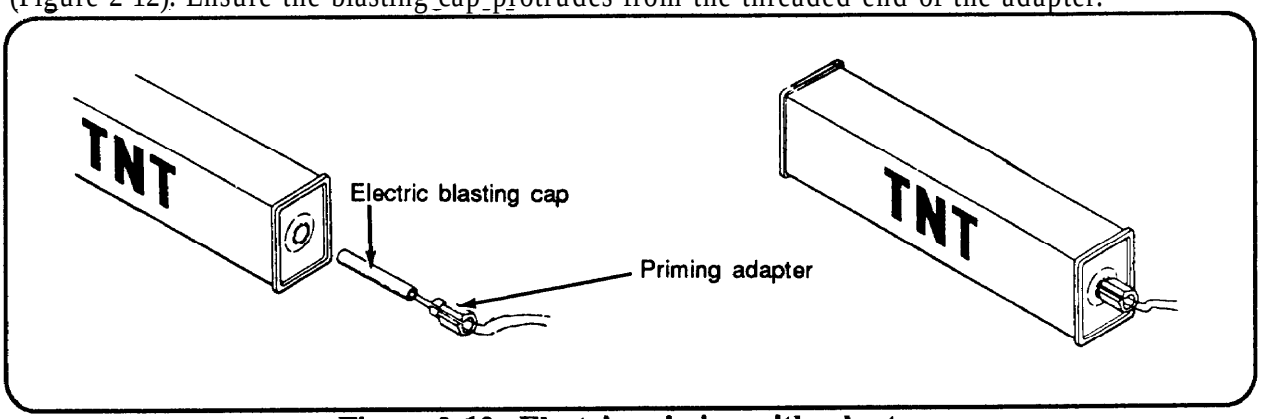


Figure 2-12. Electric priming with adapter

(c) Insert the blasting cap into the threaded cap well of the TNT block and screw the adapter into place.

(2) Without Priming Adapter. If a priming adapter is not available, use the following procedure:

(a) Prepare the electric initiation set before priming.

(b) Insert the electric blasting cap into the cap well. Tie the lead wires around the block, using two half hitches or a girth hitch (Figure 2- 13). Allow some slack in the wires between the blasting cap and the tie to prevent any tension on the blasting-cap lead wires.

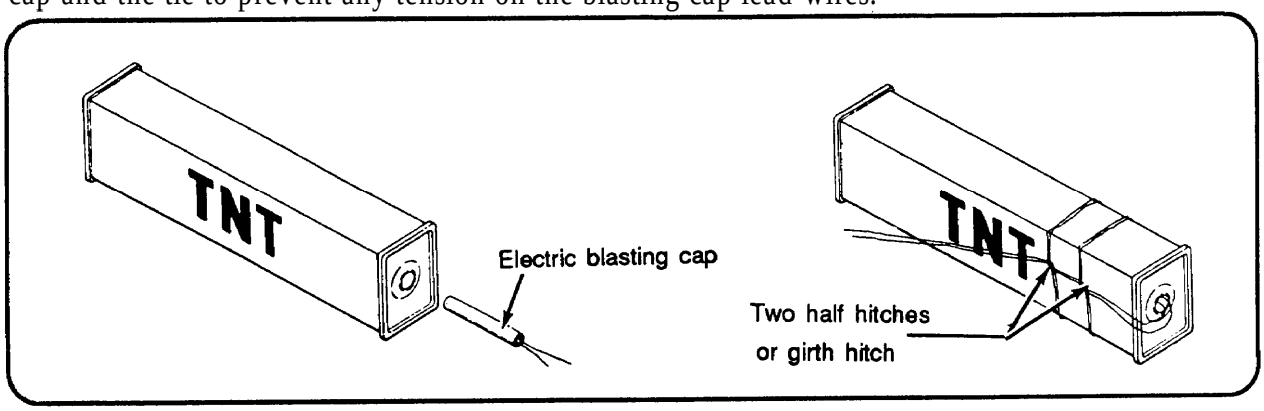


Figure 2-13. Electric priming without adapter

c. *Detonating Cord.* Use the following methods to prime TNT blocks with detonating cord:

NOTE: A 6-inch length of detonating cord equals the power output of a blasting cap. However, detonating cord will not detonate explosives as reliably as a blasting cap because its power is not as concentrated. Therefore, always use several turns or a knot of detonating cord for priming charges.

(1) Method 1 (Figure 2-14). Lay one end (l-foot length) of detonating cord at an angle across the explosive. Then, wrap the running end around the block three turns, laying the wraps over the standing end. On the fourth wrap, slip the running end under all wraps, parallel to the standing end and draw the wraps tight. Doing this forms a clove hitch with two extra turns.

(2) Method 2 (Figure 2-14). Tie the detonating cord around the explosive block with a clove hitch and two extra turns. Fit the cord snugly against the block, and push the loops close together.

(3) Method 3 (Figure 2-14). Place a loop of detonating cordon the explosive, leaving sufficient length on the end to make four turns around the block and loop with the remaining end of the detonating cord. When starting the first wrap, ensure that you immediately cross over the standing end of the loop, working your way to the closed end of the loop. Pass the free end of the detonating cord through the loop and pull it tight. This forms a knot around the outside of the block.

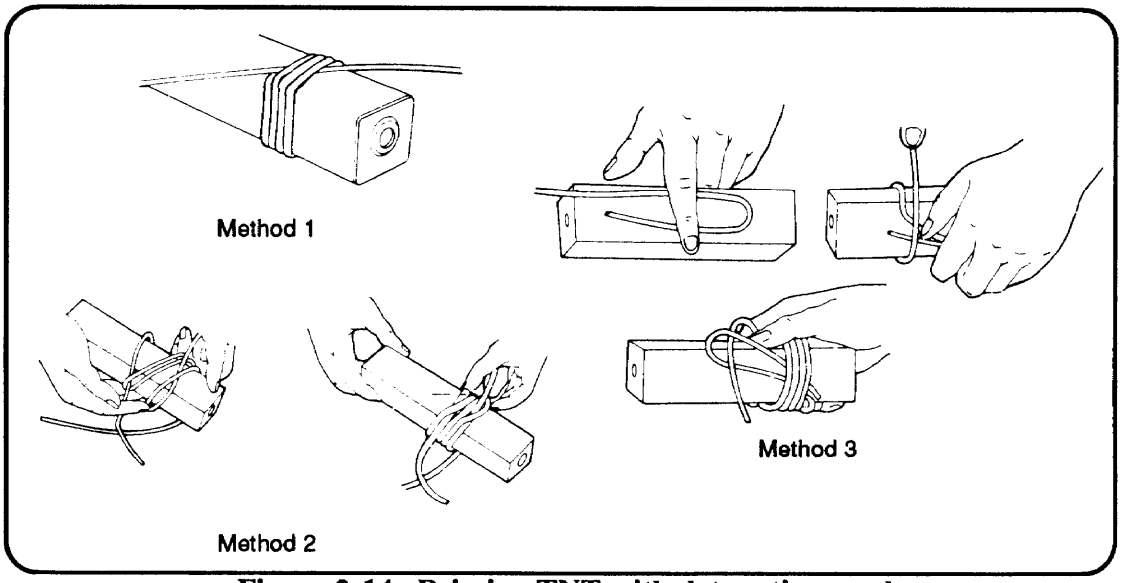


Figure 2-14. Priming TNT with detonating cord

2-5. Priming M112 (C4) Demolition Blocks.

a. *Nonelectric and Electric.* C4 blocks do not have a cap well; therefore, you will have to make one. Use the following procedure:

(1) With the M2 crimpers or other nonsparking tool, make a hole in the end or on the side (at the midpoint) large enough to hold the blasting cap.

(2) Insert the blasting cap into the hole or cut. If the blasting cap does not fit the hole or cut, do not force the cap, make the hole larger.

(3) Anchor the blasting cap in the block by gently squeezing the lastic explosive around the blasting cap.

b. *Detonating Cord.* To prime plastic explosive with detonating cord, use the following procedure:

(1) Form either a Uli knot, double overhand knot, or triple roll hot as shown in Figure 2-15.

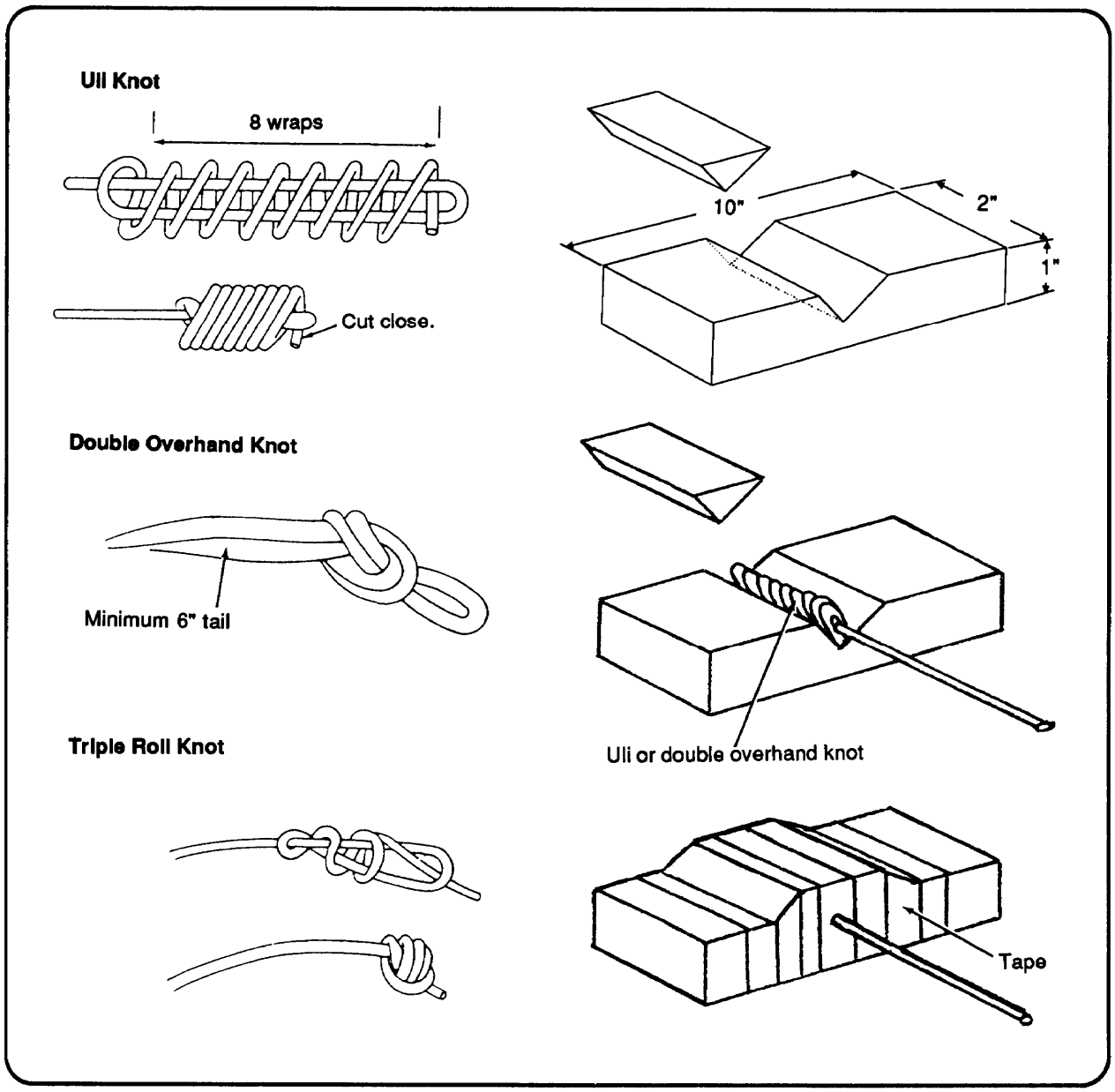


Figure 2-15. Priming plastic explosives with detonating cord

(2) Cut a notch out of the explosive, large enough to insert the knot you formed.

WARNING
Use a sharp knife on a nonsparking surface to cut explosives.

(3) Place the knot in the cut.

(4) Use the explosive you removed from the notch to cover the knot. Ensure there is at least ½ inch of explosive on all sides of the knot.

(5) Strengthen the primed area by wrapping it with tape.

NOTE: It is not recommended that plastic explosives be primed by wrapping them with detonating cord, since insufficient wraps will not properly detonate the explosive charge.

2-6. Priming M118 and M186 Demolition Charges.

a. *Nonelectric and Electric.* Use one of the following methods to prime M118 and M186 demolition charges:

(1) Method 1 (Figure 2-16, page 2- 16). Attach an M8 blasting cap holder to the end or side of the sheet explosive. Insert an electric or a nonelectric blasting cap into the holder until the end of the cap presses against the sheet explosive. The M8 blasting cap holder has three slanted, protruding teeth which prevent the clip from withdrawing from the explosive. Two dimpled spring arms firmly hold the blasting cap in the M8 holder.

(2) Method 2 (Figure 2-16, page 2-16). Cut a notch in the sheet explosive (approximately 1½ inches long and ¼ inch wide). Insert the blasting cap to the limit of the notch. Secure the blasting cap with a strip of sheet explosive.

(3) Method 3 (Figure 2-16, page 2-16). Place 1½ inches of the blasting capon top of the sheet explosive and secure it with a strip of sheet explosive (at least 3 by 3 inches).

(4) Method 4 (Figure 2-16, page 2- 16). Insert the end of the blasting cap 1½ inches between two sheets of explosive.

b. *Detonating Cord.* Sheet explosives also can be primed with detonating cord using a Uli knot, double overhand knot, or triple roll knot. Insert the knot between two sheets of explosive or place the knot on top of the sheet explosive and secure it with a small strip of sheet explosive. The knot must be covered on all sides with at least ½ inch of explosive.

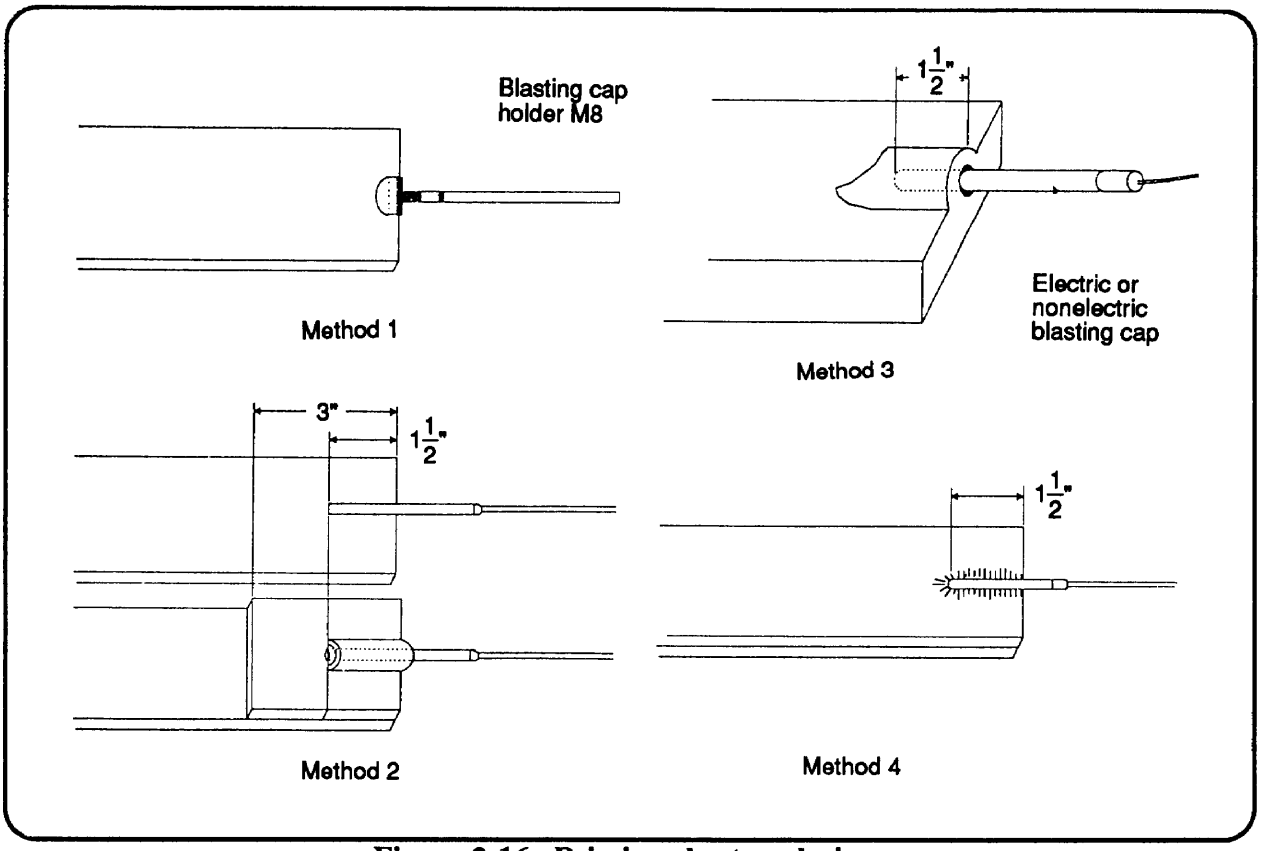


Figure 2-16. Priming sheet explosives

2-7. Priming Dynamite. Prime dynamite at either end or side. Choose the method that will prevent damage to the primer during placement.

a. *Nonelectric.* There are three methods for priming dynamite nonelectrically:

(1) End-Priming Method (Figure 2-17).

(a) Using the M2 crimpers, make a cap well in the end of the dynamite cartridge.

(b) Insert a fused blasting cap into the cap well.

(c) Tie the cap and fuse securely in the cartridge with a string.

(2) Weatherproof, End-Priming Method (Figure 2-17).

(a) Unfold the wrapping at the folded end of the dynamite cartridge.

(b) Using the M2 crimpers, make a cap well in the exposed dynamite.

(c) Insert a fused blasting cap into the cap well.

(d) Close the wrapping around the fuse and fasten the wrapping securely with a string or tape.

(e) Apply a weatherproof sealing compound to the tie.

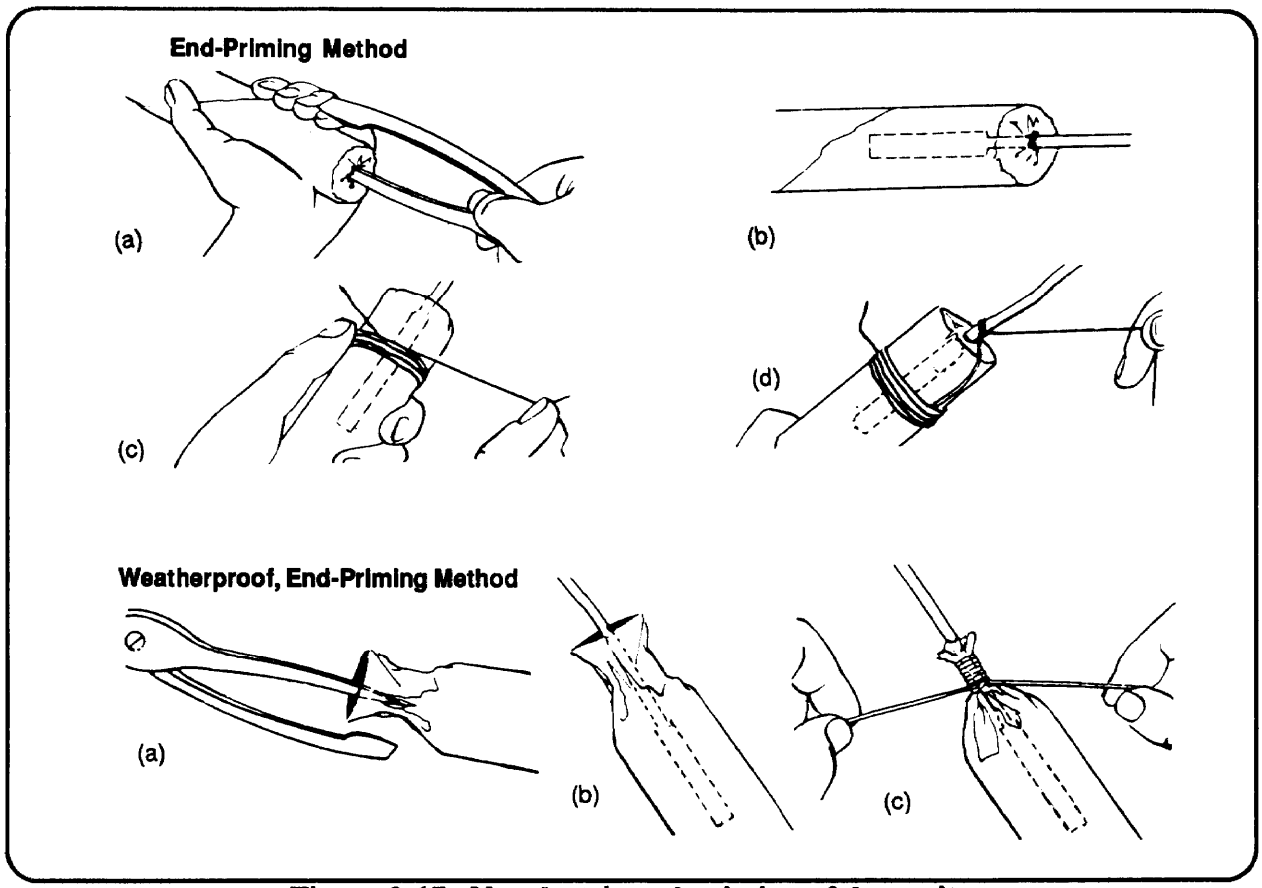


Figure 2-17. Nonelectric end priming of dynamite

(3) Side-Priming Method (Figure 2-18, page 2-18).

(a) Using the M2 crimpers, make a cap well (approximately 1½ inches long) into the side of the cartridge at one end. Slightly slant the cap well so the blasting cap, when inserted, will be nearly parallel to the side of the cartridge and the explosive end of the cap will be at a point nearest the middle of the cartridge.

(b) Insert a fused blasting cap into the cap well.

(c) Tie a string securely around the fuse. Then, wrap the string tightly around the cartridge, making two or three turns before tying it.

(d) Weatherproof the primed cartridge by wrapping a string closely around the cartrdge, extending it an inch or so on each side of the hole to cover it completely. Cover the string with a weatherproof sealing compound.

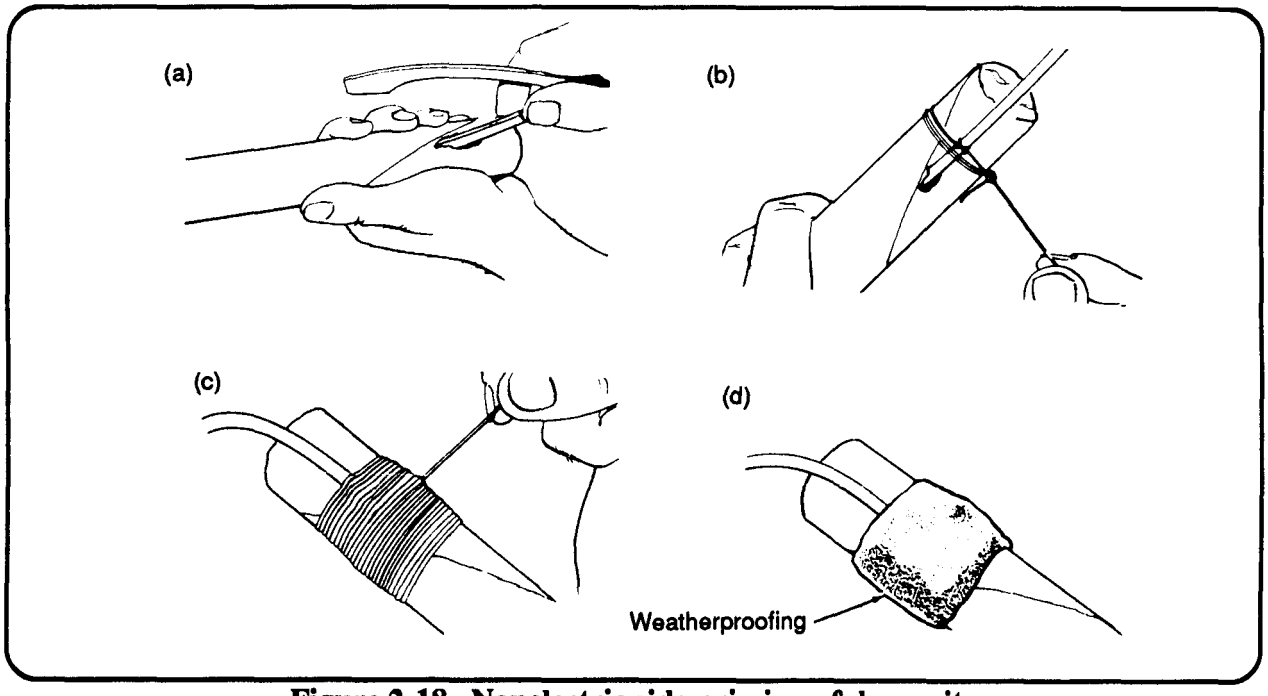


Figure 2-18. Nonelectric side priming of dynamite

b. *Electric.* Use the following method for priming with electric blasting caps:

(1) End-Priming Method (Figure 2-19).

(a) Using the M2 crimpers, make a cap well in the end of the cartridge.

(b) Using the M2 crimpers, insert an electric blasting cap into the cap well.

(c) Tie the lead wires around the cartridge with two half hitches, a string, or tape.

(2) Side-Riming Method (Figure 2-19).

(a) Using the M2 crimpers, make a cap well (approximately 1½ inches long) into the side of the cartridge at one end. Slightly slant the cap well so the blasting cap, when inserted, will be nearly parallel to the side of the cartridge and the explosive end of the cap will be at a point nearest the middle of the cartridge.

(b) Using the M2 crimpers, insert an electric blasting cap into the cap well.

(c) Tie the lead wire around the cartridge with two half hitches, a string, or tape.

c. *Detonating Cord.* You also can use detonating cord to prime dynamite. Using the M2 crimpers, start approximately 1 inch from either end of the dynamite charge and punch four equally spaced holes through the dynamite cartridge (Figure 2-20). Make sure to rotate the cartridge 180 degrees after punching each hole to keep the holes parallel. Lace detonating cord through the holes in the same direction the holes were punched. Take care not to pull the loops of the detonating cord too tightly or the dynamite will break. Secure the detonating cord tail by passing it between the detonating cord lace and the dynamite charge.

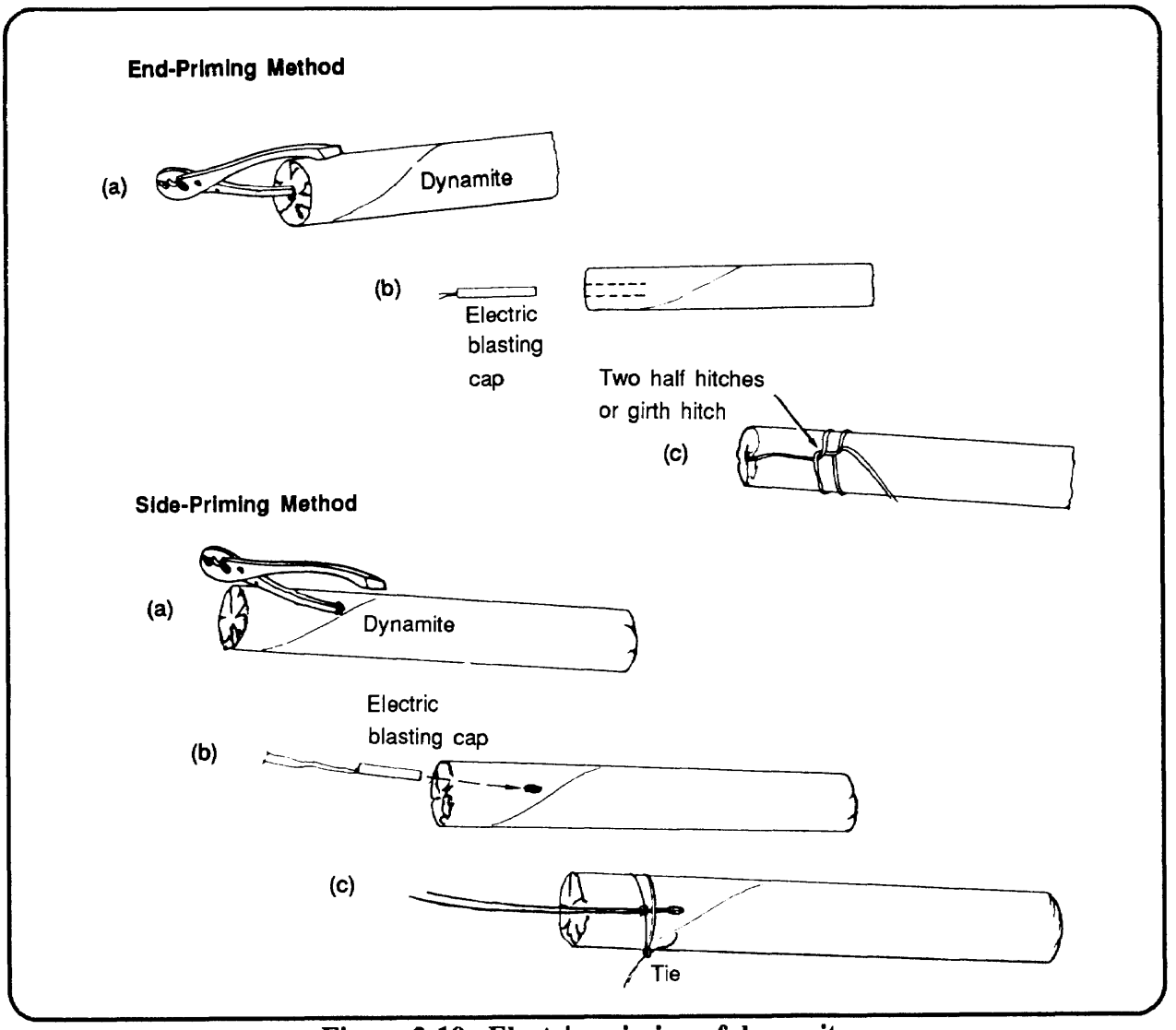


Figure 2-19. Electric priming of dynamite

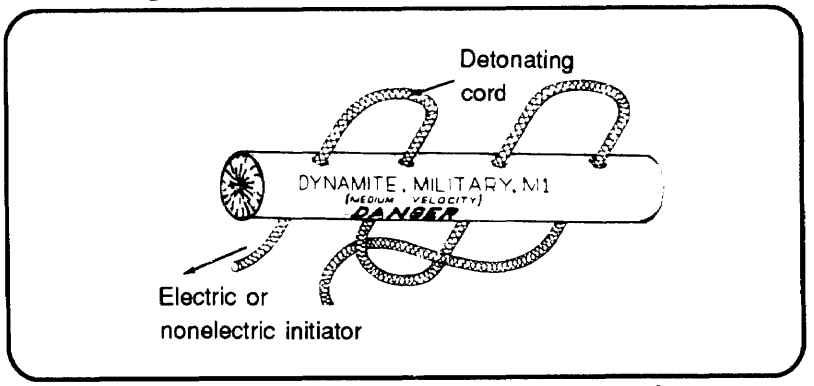


Figure 2-20. Priming dynamite with detonating cord

2-8. Priming 40-Pound, Ammonium-Nitrate Cratering Charges. Because the cratering charge is primarily an underground charge, prime it only with detonating cord. Use dual priming to protect against misfires (Figure 2-21, diagram 2, page 2-20). Use the following procedure:

a. Tie an overhand knot, with a 6-inch overhang, at one end of the length of detonating cord.

b. Pass the opposite end of the detonating cord up through the detonating cord tunnel (Figure 2-21, diagram 1) of the cratering charge.

WARNING
Ammonium nitrate is hydroscopic. When wet, ammonium nitrate is ineffective. Therefore, inspect the metal container for damage or rust. Do not use damaged or rusty charges.

c. When dual priming a single 40-pound cratering charge, use a minimum of one pound of explosive. Prime a block of TNT or package of C4 with detonating cord (paragraphs 2-4c, page 2-13, and 2-5b, page 2-14, respectively) and tape this charge to the center of the cratering charge (Figure 2-21, diagram 2). The detonating cord branch lines must be long enough to reach the detonating-cord ring mains after the cratering charge is in the ground. Twelve-foot branch lines should be adequate. When placing two cratering charges in the same borehole, prime only the detonating cord tunnels of each charge. In this manner, the borehole is dual-primed and extra explosives are not required, as shown in Figure 2-21, diagram 3.

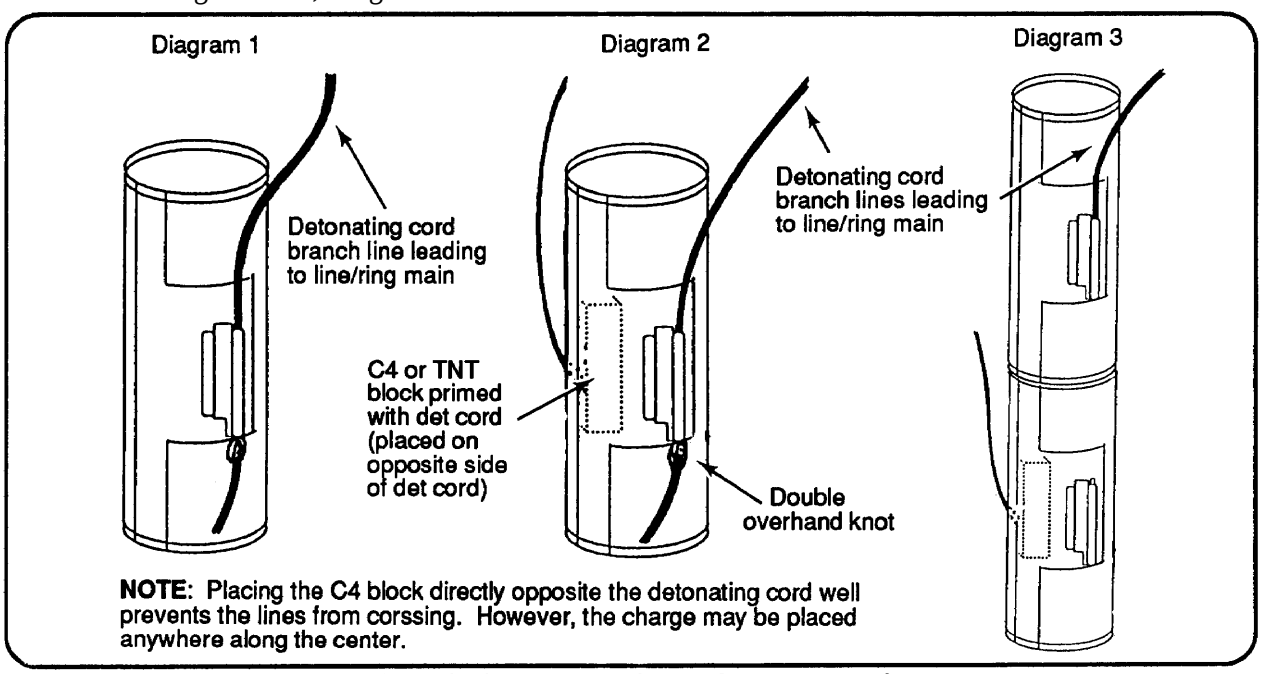


Diagram 1
Diagram 2
Diagram 3
Detonating cord branch line leading to line/ring main
C4 or TNT block primed with det cord (placed on opposite side of det cord)
Detonating cord branch lines leading to line/ring main
Double overhand knot
NOTE: Placing the C4 block directly opposite the detonating cord well prevents the lines from corssing. However, the charge may be placed anywhere along the center.

Figure 2-21. Priming ammonium-nitrate cratering charge

2-9. Priming M2A4 and M3A1 Shaped Charges. The M2A4 and M3A1 are primed only with electric or nonelectric blasting caps. These charges have a threaded cap well at the top of the cone. Prime them with a blasting cap as shown in Figure 2-22. Use a piece of string, cloth, or tape to hold the cap if a priming adapter is not available. Simultaneously detonate multiple shaped charges to create a line of boreholes for cratering charges by connecting each charge into a detonating-cord ring or line main. Use the following procedure for priming shaped charges:

WARNING
Do not dual prime shaped charges. Prime them only with a blasting cap in the blasting cap well.

a. Crimp a nonelectric blasting cap to a branch line.

b. Connect the branch line to the ring main.

c. Insert the blasting cap into the blasting cap well of the shaped charge.

d. When detonating multiple shaped charges, make all branch-line connections before priming any shaped charges.

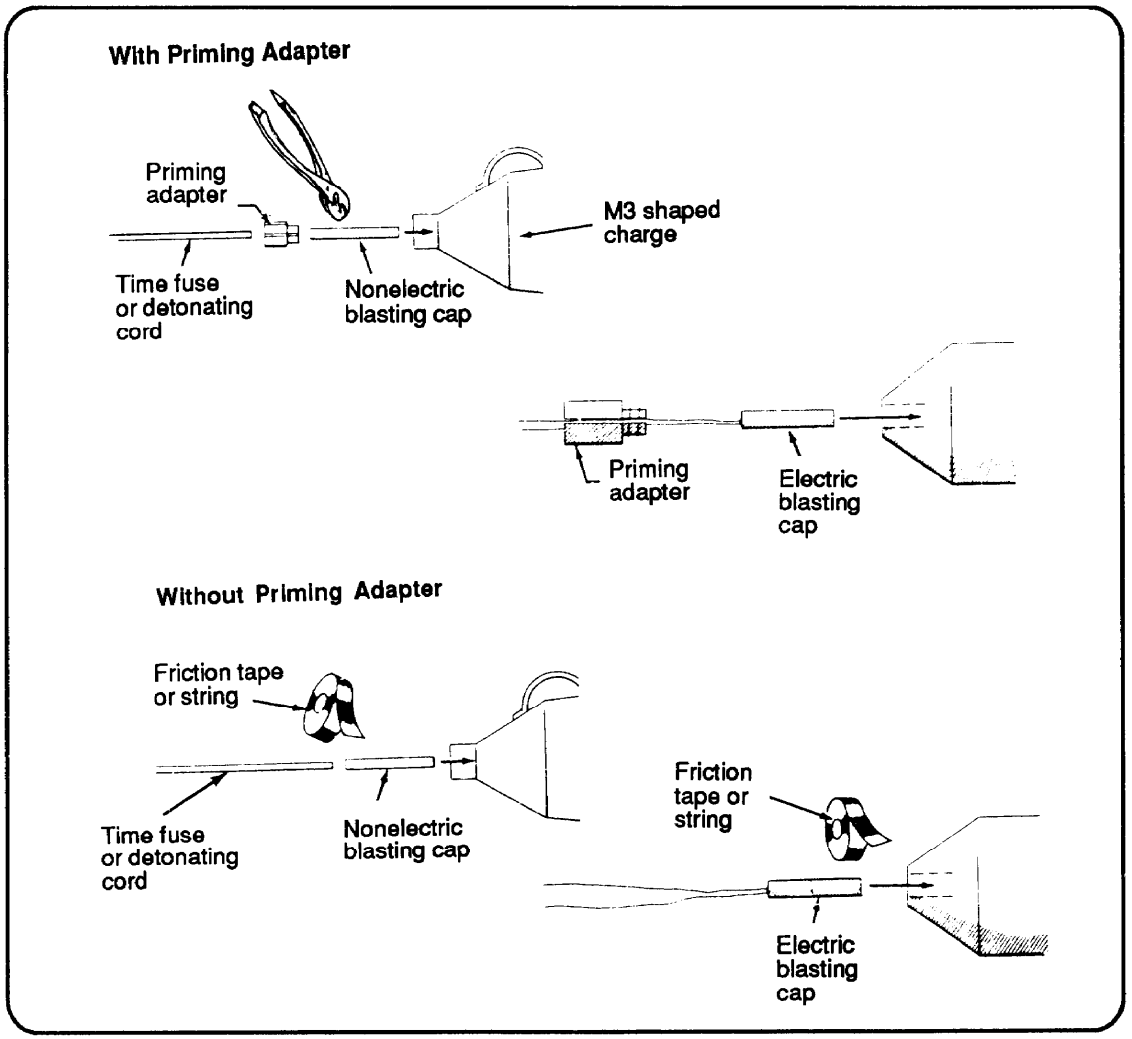


Figure 2-22. Priming shaped charges

2-10. Priming the Bangalore Torpedo.

a. *Nonelectric.* Insert the blasting cap of a nonelectric initiation set directly into the cap well of a torpedo section. If a priming adapter is not available, use tape or string to hold the blasting cap in place (Figure 2-23, diagram 1, page 2-22).

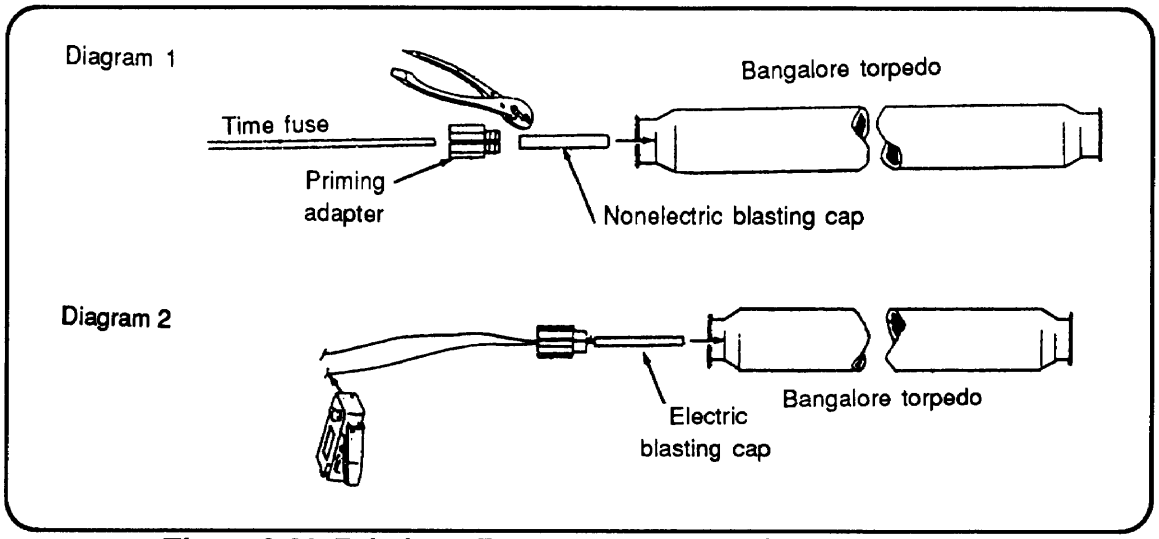


Figure 2-23. Priming a Bangalore torpedo with a blasting cap

b. *Electric.* Insert the blasting cap of an electric initiation set into the cap well of a torpedo section. If a priming adapter is not available, hold the cap in place by taping or tying (with two half hitches) the lead wires to the end of the torpedo. Allow some slack in the wires between the blasting cap and the tie to prevent tension on the blasting cap leads.

c. *Detonating Cord.* Prime the torpedo by wrapping detonating cord eight times around the end of the section, just below the bevel (Figure 2-24). After pulling the knot tight, insert the short end of the detonating cord into the cap well and secure it with tape. Never use the short end (tail) of the detonating cord to initiate the torpedo. Initiation must come from the running end of the detonating cord.

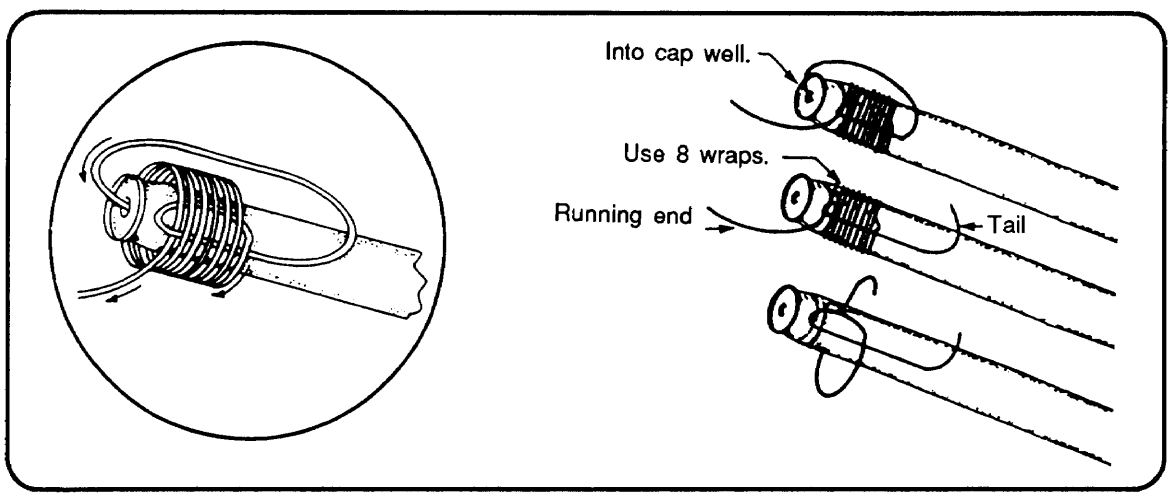


Figure 2-24. Priming a Bangalore torpedo with detonating cord

WARNING

Do not use more than or less than eight wraps to prime the Bangalore torpedo. Too many wraps will extend the detonating cord past the booster charge housing, possibly causing the torpedo to be cut without detonating. Too few wraps may cause the torpedo to only be crimped, without detonating.

Section III. Firing Systems

2-11. Types of Firing Systems. There are two types of firing systems: single and dual. Chapter 5 covers the tactical applications for these systems.

a. *Single.* Figure 2-25 shows a single-firing system Each charge is singly primed with a branch line. The branch line is tied to the line main or ring main. (Tying to the ring main is preferred but construction of a ring main may not be possible because of the amount of detonating cord. The ring main decreases the chances of a missfire should a break or cut occur anywhere within the ring main.) The electric, nonelectric, or combination initiation systems are then taped onto the firing system. When using a combination initiation system, the electric initiation system is always the primary means of initiation. When using dual, nonelectric initiation systems, the shorter time fuse is the primary initiation system (Figure 2-26).

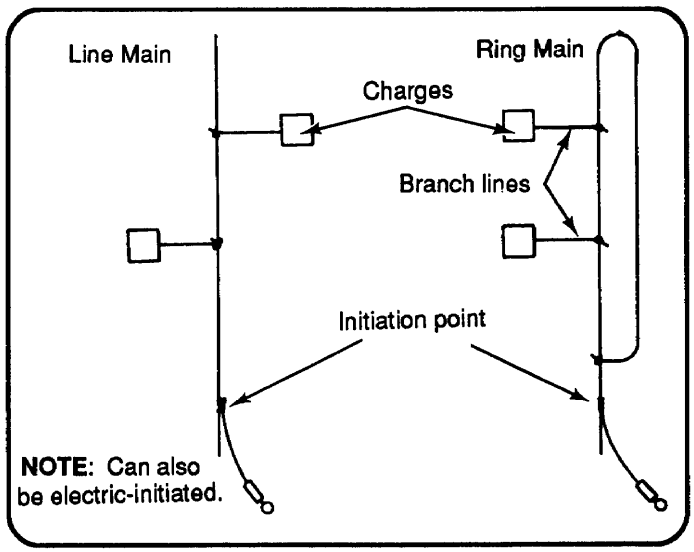


Figure 2-25. Single-firing system (single-initiated, single-fired, single-primed)

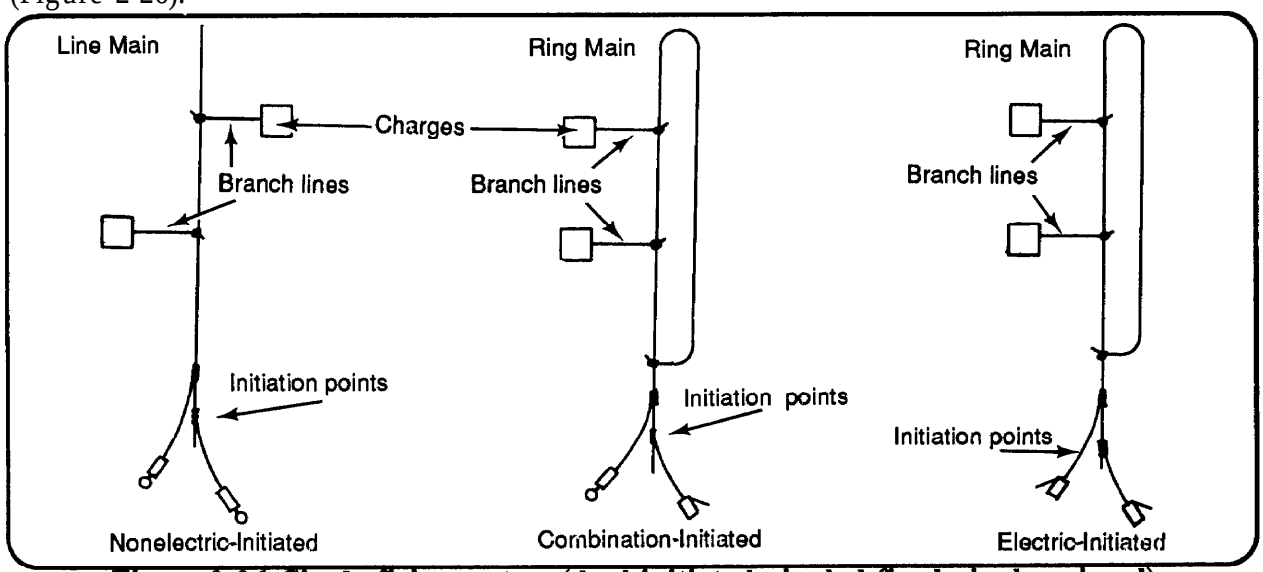


Figure 2-26. Single-firing system (dual-initiated, singled-fired, single-primed)

b. *Dual.* Figure 2-27 (page 2-24) shows a dual-firing system. Each charge is dual-primed with two branch lines (Figure 2-28, page 2-24). One branch line is tied to one firing system, and the other branch line is tied to an independent firing system. Line mains or ring mains may be used; however, they should not be mixed. To help prevent misfires, use detonating-cord crossovers. Crossovers are used to tie both firing systems together at the ends. The initiation systems are taped in—the primary initiation system goes to one firing system, the secondary goes to the other.

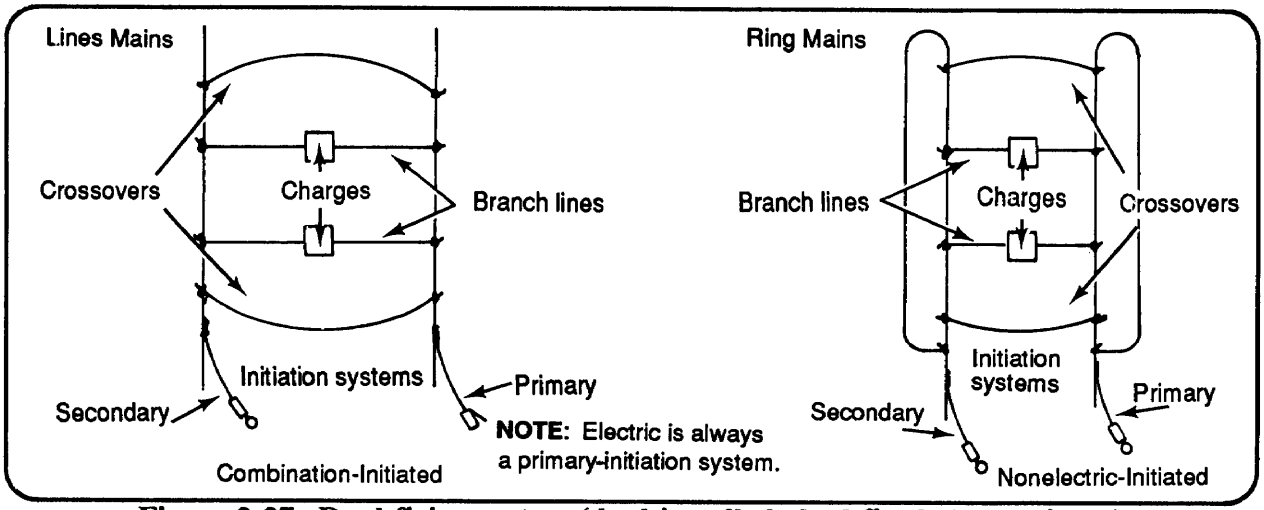


Figure 2-27. Dual-firing system (dual-installed, dual-fired, dual-primed)

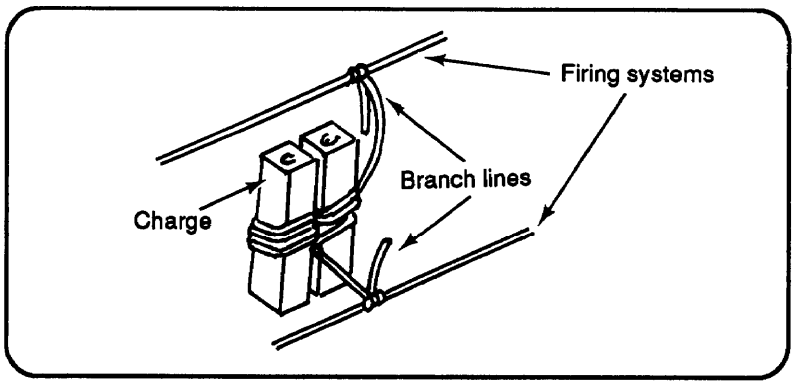


Figure 2-28. Dual-primed charge

Figure 2-29 shows a dual-firing system using horizontal and vertical ring mains. The complexity of a target or obstacle may necessitate using multiple line mains or ring mains for simultaneous detonation. These will be referred to as horizontal and vertical lines or ring mains.

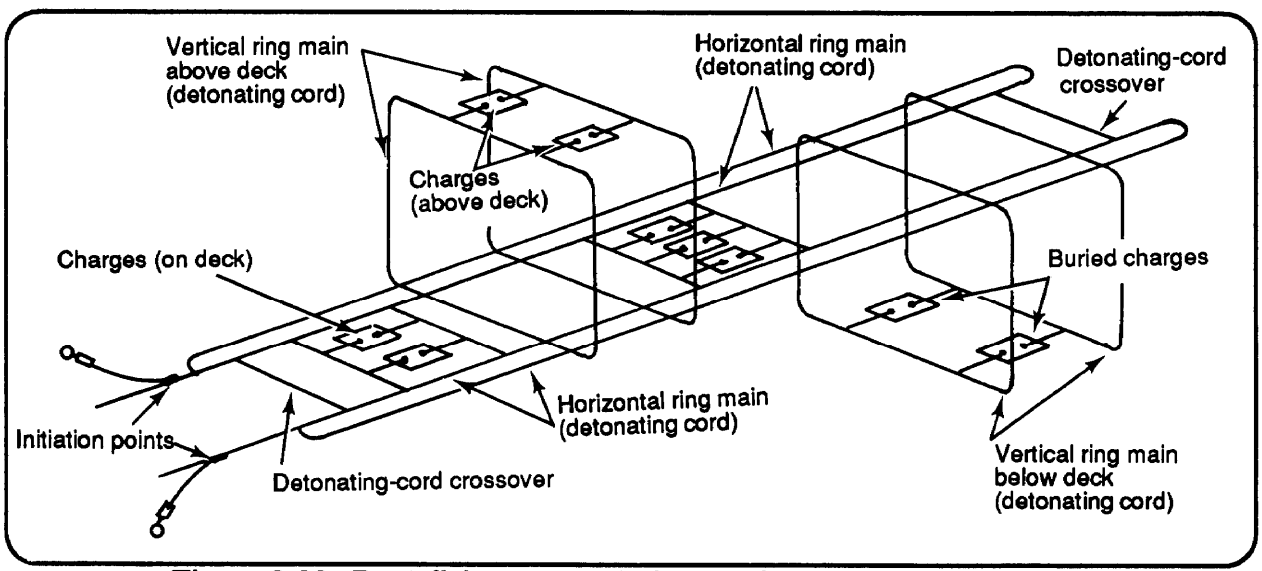


Figure 2-29. Dual-firing system (using a bridge as a possible target)

2-12. Detonating Cord. A firing system uses detonating cord to transmit a shock wave from the initiation set to the explosive charge. Detonating cord is versatile and easy to install. It is useful for underwater, underground, and above-ground blasting because the blasting cap of the initiation set may remain above water or above ground and does not have to be inserted directly into the charge. Detonating-cord firing systems combined with detonating-cord priming are the safest and most efficient ways to conduct military demolition missions. Initiate detonating cord only with nonelectric or electric initiation sets.

2-13. Attaching the Blasting Cap. Attach the blasting cap, electric or nonelectric, to the detonating cord with tape. You can use string, cloth, or fine wire if tape is not available. Tape the cap securely to a point 6 inches from the end of the detonating cord to overcome moisture contamination. The tape must not conceal either end of the cap. Taping in this way allows you to inspect the cap in case it misfires. No more than 1/8 inch of the cap needs to be left exposed for inspection (Figure 2-30).

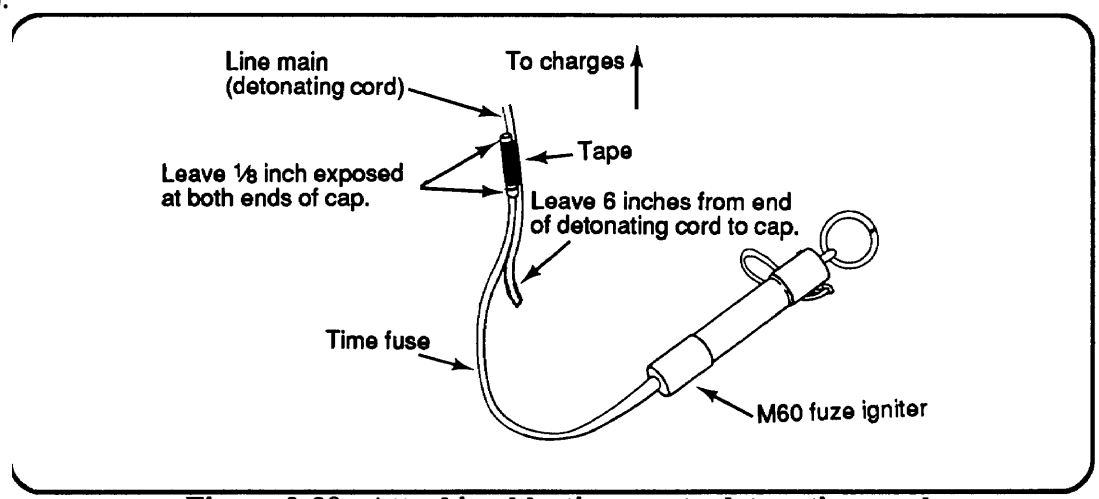


Figure 2-30. Attaching blasting cap to detonating cord

2-14. Detonating-Cord Connections. Use square knots or detonating-cord clips to splice the ends of detonating cord (Figure 2-31). Square knots may be placed in water or in the ground, but the cord must be detonated from a dry end or above ground. Allow 6-inch tails on square knots to prevent misfires from moisture contamination. Paragraph 1-21 (page 1-17) describes the process for connecting detonating cord with detonating-cord clips.

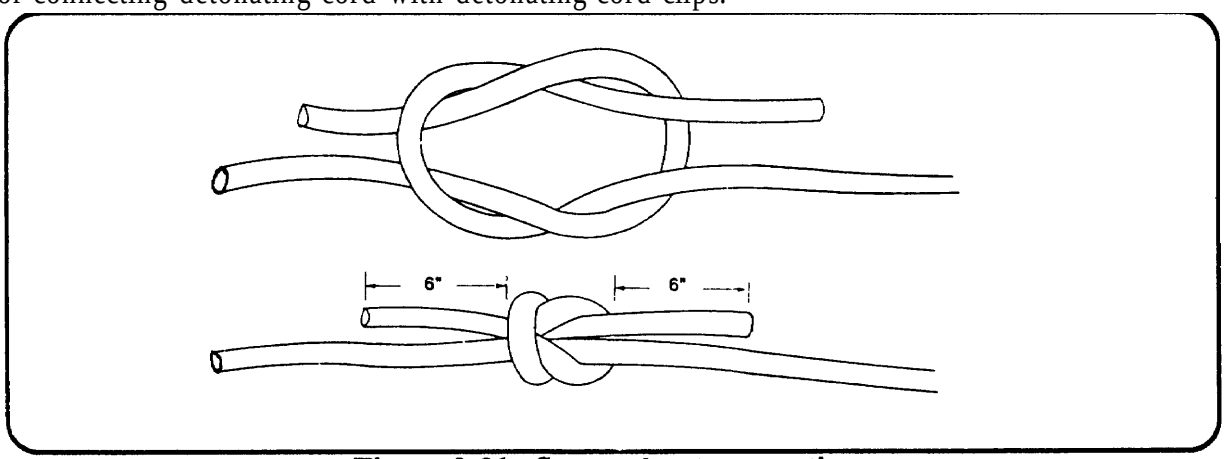


Figure 2-31. Square-knot connections

a. *Branch Line.* A branch line is nothing more than a length of detonating cord. Attach branch lines to a detonating-cord ring or line main to fire multiple charges. Combining the branch line with an initiation set allows you to fire a single branch line. If possible, branch lines should not be longer than 12 feet from the charge to the ring or line main. A longer branch line is too susceptible to damage that may isolate the charge. Fasten a branch line to a main line with a detonating-cord clip (Figure 1-18, page 1-17) or a girth hitch with an extra turn (Figure 2-32). The connections of branch lines and ring or line mains should intersect at right (90-degree) angles. If these connections are not at right angles, the branch line may be blown off the line main without complete detonation. To prevent moisture contamination and ensure positive detonation, leave at least 6 inches of the running end of the branch line beyond the tie. It does not matter which side of the knot your 6-inch overhang is on at the connection of the ring or line main.

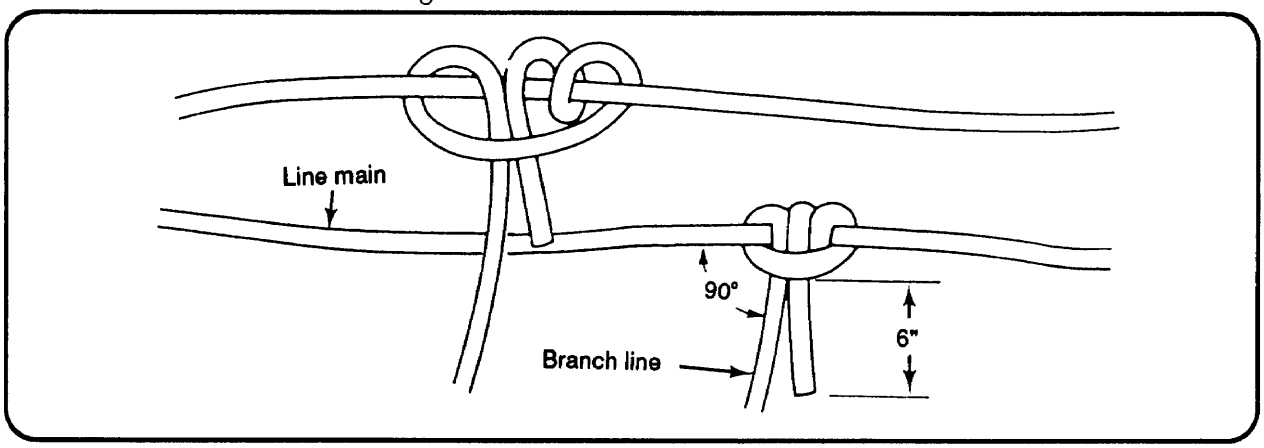


Figure 2-32. Girth hitch with an extra turn

b. *Ring Main.* Ring mains are preferred over line mains because the detonating wave approaches the branch lines from two directions. The charges will detonate even when them is a break in the ring main. A ring main will detonate an almost unlimited number of charges. Branch-line connections at the ring main should be at right angles. Kinks in the lines should not be sharp. You can connect any number of branch lines to the ring main; however, never connect a branch line (at the point) where the ring main is spliced. When making branch-line connections, avoid crossing lines. If a line crossing is necessary, provide at least 1 foot of clearance between the detonating cords. Otherwise, the cords will cut each other and destroy the firing system.

(1) Method 1. Make a ring main by bringing the line main back in the form of a loop and attaching it to itself with a girth hitch with an extra turn (Figure 2-33, diagram 1).

(2) Method 2. Make a ring main by making a U-shape with the detonating cord, and then attaching a detonating-cord crossover at the open end of the U. Use girth hitches with extra turns when attaching the crossover (Figure 2-33, diagram 2). An advantage of the U-shaped ring main is that it provides two points of attachment for initiation sets.

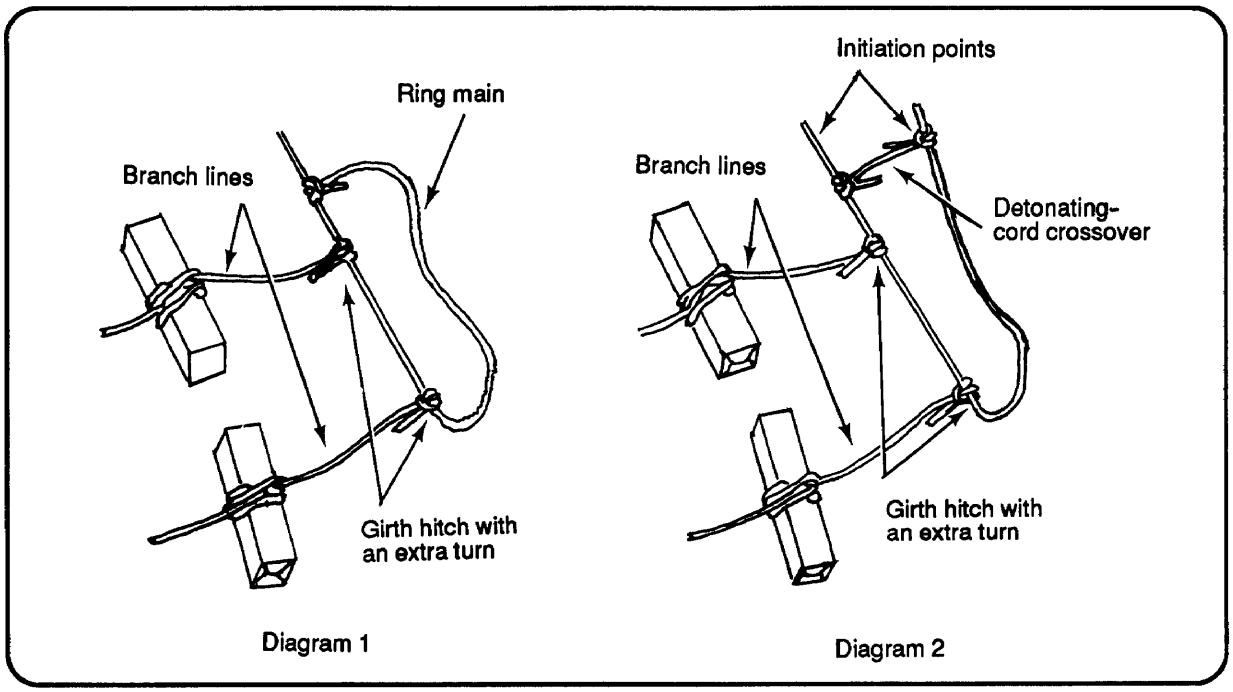


Figure 2-33. Ring mains

c. *Line Main.* A line main will fire multiple charges (Figure 2-34), but if a break in the line occurs, the detonating wave will stop at the break. When the risk of having a line main cut is unacceptable, use a ring main. Use line mains only when speed is essential and a risk of failure is acceptable. You can connect any number of branch lines to a line main. However, connect only one branch line at any one point unless you use a junction box (Figure 2-35, page 2-28).

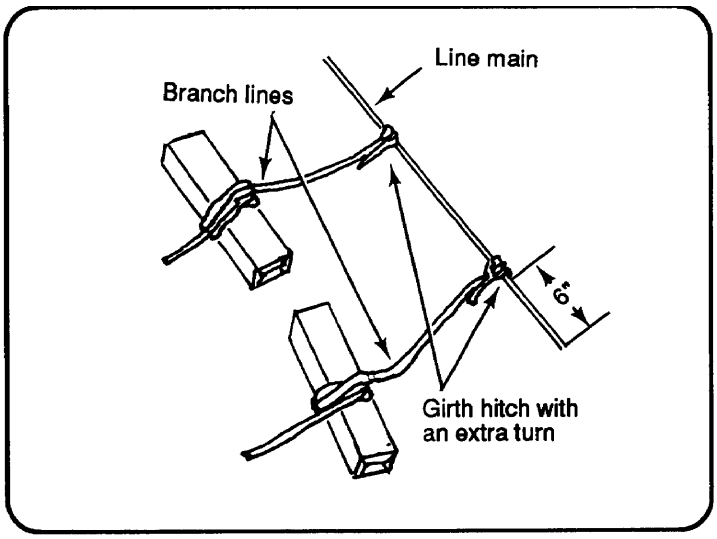


Figure 2-34. Line main with branch lines

2-15. Initiating Lines and Mains.

a. *Line Main and Branch Line.* Whenever possible, dual initiate a line main or a branch line (Figure 2-36, page 2-28). Place the blasting cap that will detonate first closest to the end of the detonating cord (for example, the electric cap of a combination of initiation sets). Doing this will ensure the integrity of the backup system when the first cap detonates and fails to initiate the line main. Do not try to get both caps to detonate at the same time. This is virtually impossible to do with time fuse. Stagger the detonations a minimum of 10 seconds.

b. *Ring Main.* Initiate ring mains as shown in Figures 2-33. The blasting caps are still connected as shown in Figure 2-36 (page 2-28), but by having one on each side of the ring main, the chances of both caps becoming isolated from the ring are greatly reduced.

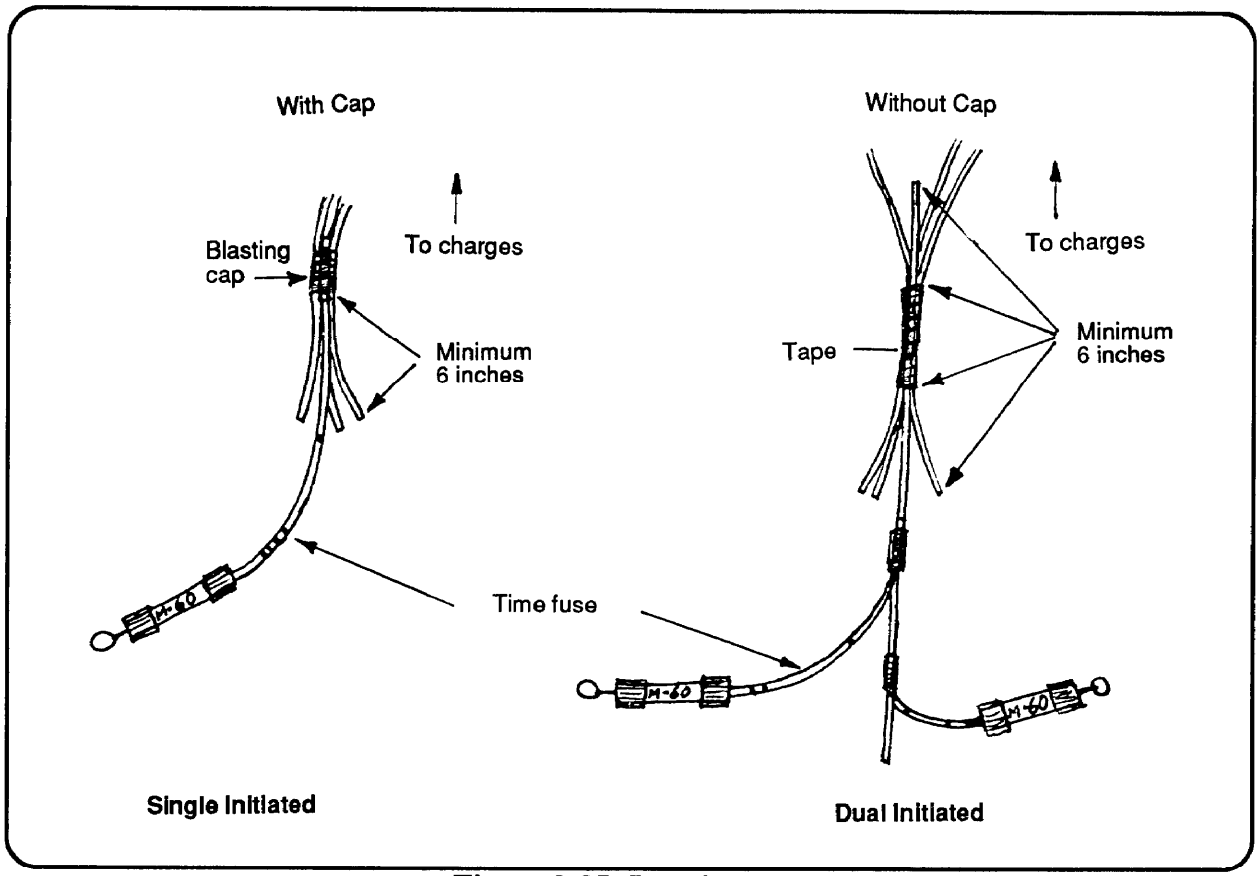


Figure 2-35. Junction box

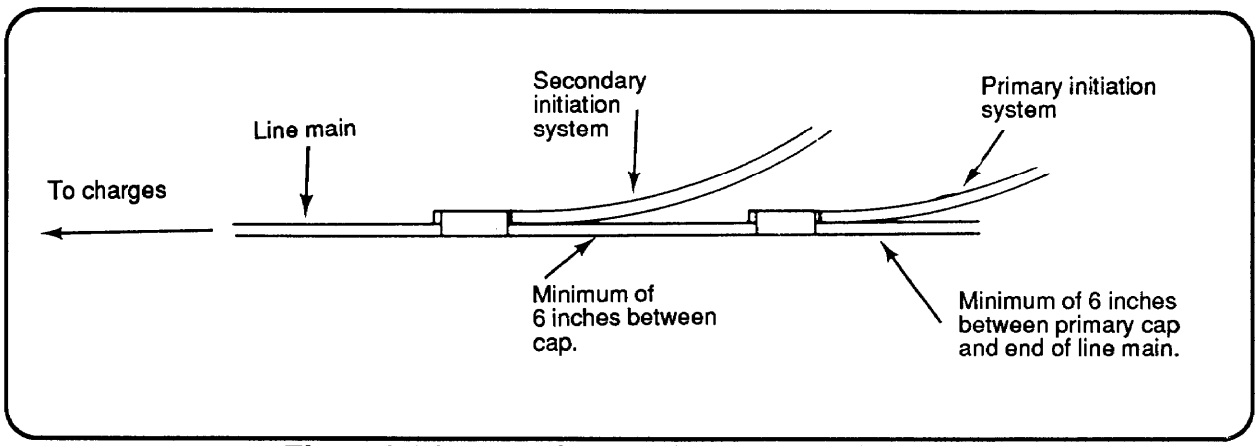

Secondary initiation system
Primary initiation system
Line main
To charges
Minimum of 6 inches between cap.
Minimum of 6 inches between primary cap and end of line main.

Figure 2-36. Attaching blasting caps to a line main

WARNING

When using time or safety fuse, uncoil it and lay it out in a straight line. Place the time fuse so that the fuse will not curl up and prematurely detonate the blasting cap crimped to it.

Chapter 3
Calculation and Placement of Charges

Section I. Demolition

3-1. Principles. The amount and placement of explosives are key factors in military demolition projects. Formulas are available to help the engineer calculate the required amount of explosives. Demolition principles and critical-factor analysis also guide the soldier in working with explosive charges. The available formulas for demolition calculations are based on the follwing factors:

a. *Effects of Detonation.* When an explosive detonates, it violently changes into highly compressed gas. The explosive type, density, confinement, and dimensions determine the rate at which the charge changes to a gaseous state. The resulting pressure then forms a compressive shock wave that shatters and displaces objects in its path. A high-explosive charge detonated in direct contact with a solid object produces three detectable destructive affects:

(1) Deformation. The charge's shock wave deforms the surface of the object directly under the charge. When the charge is placed on a concrete surface, it causes a compressive shock wave that crumbles the concrete in the immediate vicinity of the charge, forming a crater. When placed on a steel surface, the charge causes an indentation or depression about the size of the contact area of the charge.

(2) Spall. The charge's shock wave chips away at the surface of the object directly under the charge. This action is known as *spalling.* If the charge is large enough, it will span the opposite side of the object. Because of the difference in density between the target and the air, the charge's compressive shock wave reflects as a tensile shock wave from the free surface, if the target has a free surface on the side opposite the charge. This action causes spalling of the target-free surface. The crater and spans may meet to forma hole through the wall in concrete demolitions. On a steel plate, the charge may create one span in the shape of the explosive charge, throwing the spall from the plate.

(3) Radial Cracks. If the charge is large enough, the expanding gases can create a pressure load on the object that will cause cracking and therefore displace the material. This effect is known as *radial cracking.* When placed on concrete walls, the charge may crack the surface into a large number of chunks and project them away from the center of the explosion. When placed on steel plates, the charge may bend the steel away from the center of the explosion.

b. *Significance of Charge Dimensions.* The force of an explosion depends on the quantity and power of the explosive. The destructive effect depends on the direction in which the explosive force is directed. To transmit the greatest shock, the charge must have the optimal relationship of contact area and thickness to target volume and density. If you spread a calculated charge too thinly, you will not have provided enough space for the shock wave to reach full velocity before striking the target. In improperly configured explosives (too thin or wrong strength), the shock wave tends to travel in a parallel rather than a perpendicular direction to the surface. As a result, the volume of the target will be too much for the resulting shockwave. Additionally, a thick charge with too small

a contact area will transmit a shock wave over too small a target area, with much lateral loss of energy.

c. *Significance of Charge Placement.* The destructive effect of an explosive charge also depends on the location of the charge in relation to the target size, shape, and configuration. For the most destructive effect, detonate an explosive of the proper size and shape for the size, shape, and configuration of the target. Any significant air or water gap between the target and explosive will lessen the force of the shock wave. Cut explosives (such as sheet or plastic explosives) to fit odd-shaped targets. Whenever possible, place explosive charges to act through the smallest part of the target. Use internal charges to achieve maximum destruction with minimum explosives expense. Tamping external charges increases their destructive effect.

3-2. Types of Charges.

a. *Internal Charges.* Place internal charges in boreholes in the target. Confine the charges with tightly packed sand, wet clay, or other material (stemming). *Stemming* is the process of packing material on top of an internal borehole or crater charge. Fill and tamp stemming material against the explosive to fill the borehole to the surface. In drill holes, tamp the explosive as it is loaded into the hole. Tamp stemming material only with nonsparking equipment.

b. *External Charges.* Place external charges on the surface of the target. Cover and tamp the charges with tightly packed sand, clay, or other dense material. Stemming material may be loose or in sandbags. To be most effective, make the thickness of the tamping material at least equal to the breaching radius. Tamp small breaching charges on horizontal surfaces with several inches of wet clay or mud.

3-3. Charge Calculations. Determine the amount of explosives required for any demolition project by calculation, based on the following critical factors:

a. *Type and Strength of Materials in Targets.* A target may be timber, steel, or other material. Concrete may be reinforced with steel, thereby increasing the concrete's strength.

b. *Size, Shape, and Configuration of Target.* These characteristics all influence the required type and amount of explosives. For example, large or odd-shaped targets, such as concrete piers and steel beams, are more economically demolished with multiple charges than with a single charge.

c. *Desired Demolition Effect.* Consider the extent of the demolition project and the other desired effects, such as the direction trees will fall when constructing an abatis.

d. *Type of Explosive.* The characteristics of each type of explosive determine its application for demolition purposes. Tables 1-1 and 1-2 (pages 1-2 and 1-5) list these characteristics.

e. *Size and Placement of Charge.* When using external charges without considering placement techniques, use a flat, square charge with a thickness-to-width ratio of 1:3. In general, charges of less than 5 pounds should be at least 1 inch thick. Charges from 5 to 40 pounds should be 2 inches thick. Charges of 40 pounds or more should be 4 inches thick. Fasten charges to the target using wire, adhesive compound, tape, or string. Prop charges against targets with wooden or metal frames made of scrap or other available materials or place the charges in boreholes.

f. *Method of Tamping.* If you do not completely seal or confine the charge or if you do not ensure the material surrounding the explosive is balanced on all sides, the explosive's force will

escape through the weakest spot. To keep as much explosive force as possible on the target, pack material around the charge to fill any empty space. This material is called *tamping material* and the process is called *tamping*. Sandbags and earth are examples of common tamping materials. Always tamp charges with a nonsparking instrument.

g. *Direction of Initiation.* The direction in which the shockwave travels through the explosive charge will affect the rate of energy transmitted to the target. If the shock wave travels parallel to the surface of the target (Figure 3-1, diagram 1), the shock wave will transmit less energy over a period of time than if the direction of detonation is perpendicular to the target (Figure 3-1, diagram 2). For best results, initiate the charge in the center of the face opposite the face in contact with the target.

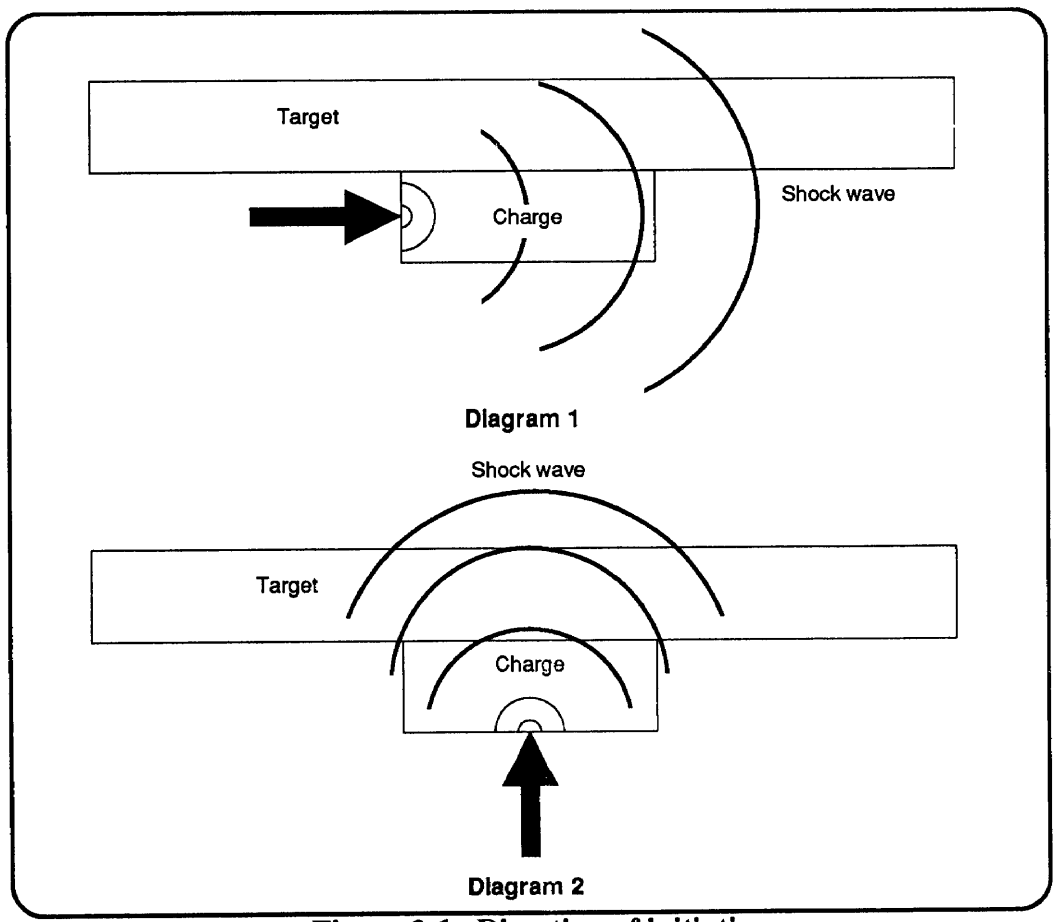


Figure 3-1. Direction of initiation

3-4. Charge Selection and Calculation.

a. *Selection.* Explosive selection for successful demolition operations is a balance between the critical factors listed above and the practical aspects: target type; the amount and types of explosives, materials (such as sandbags), equipment, and personnel available; and the amount of time available to accomplish the mission.

b. *Calculation.* Use the following procedure to determine the weight *(P)* of the explosive required for a demolition task, in pounds of TNT. If you use an explosive other than TNT, adjust *P* accordingly by dividing *P* for TNT by the relative effectiveness (RE) factor of the explosive you

plan to use (Table 1-1, page 1-2). Use the following six-step, problem-solving format for all charge calculations:

(1) Determine the critical dimensions of the target.

(2) Calculate the weight of a single charge of TNT to two decimal places by using the appropriate demolition formula (do not round). If your calculations are for TNT, skip to Step 4.

(3) Divide the quantity of explosive by the RE factor (carry the calculations to two decimal places, and do not round). If you are using TNT, skip this step.

(4) Determine the number of packages of explosive for a single charge by dividing the individual charge weight by the standard package weight of the chosen explosive. Round this result to the next-higher, whole package. Use volumes instead of weights for special purpose charges (ribbon, diamond, saddle, and similar charges).

(5) Determine the number of charges for the target.

(6) Determine the total quantity of explosives required to destroy the target by multiplying the number of charges (Step 5) by the number of packages required per charge (Step 4).

Section II. Normal Cutting Charges

3-5. Timber-Cutting Charges. Plastic explosives are the best timber-cutting charges for both internal and external placement. These explosives are good internal charges because you can easily tamp them into boreholes. They make excellent external charges, as they are easy to tie, tape, or fasten to the target. Timber will vary widely in its physical properties from location to location, requiring careful calculation. Therefore, make test shots on the specific type of timber to determine the optimal size of the timber-cutting charge. Example A-1 (page A-1) shows how to calculate internal timber-cutting charges.

a. *Internal Charges.* Use the following formula to calculate internal cutting charges:

$$P = \frac{D^2}{250} \text{ or } P = 0.004D^2 \qquad \textbf{(3-1)}$$

where–

P = TNT (or equivalent) required per tree, in pounds.
D = diameter or least dimension of dressed timber, in inches.

Use one hole to place the explosive in trees up to 18 inches in diameter. For larger trees, use two holes, drilled at right angles to each other without intersecting, but as close together as possible. Drill 2-inch diameter holes to a depth equal to two-thirds the diameter of the tree. Split the required charge evenly between the holes. Doing this will allow enough room to place the explosive in the holes and leave enough room to cap them with mud or clay (Figure 3-2). For dimensioned timber requiring two boreholes, place the boreholes side by side. When placing the charges, form the plastic explosive to approximate the diameter of the hole. Try to minimize the amount of molding so as not to reduce the density of the explosive. Prime the charge with detonating cord (paragraph 2-5b, page 2-14) and place the charge in the hole. Finish filling the holes by packing them with

mud or clay, using a nonsparking tool. When using two boreholes, connect the branch lines in a junction box (Figure 2-35, page 2-27).

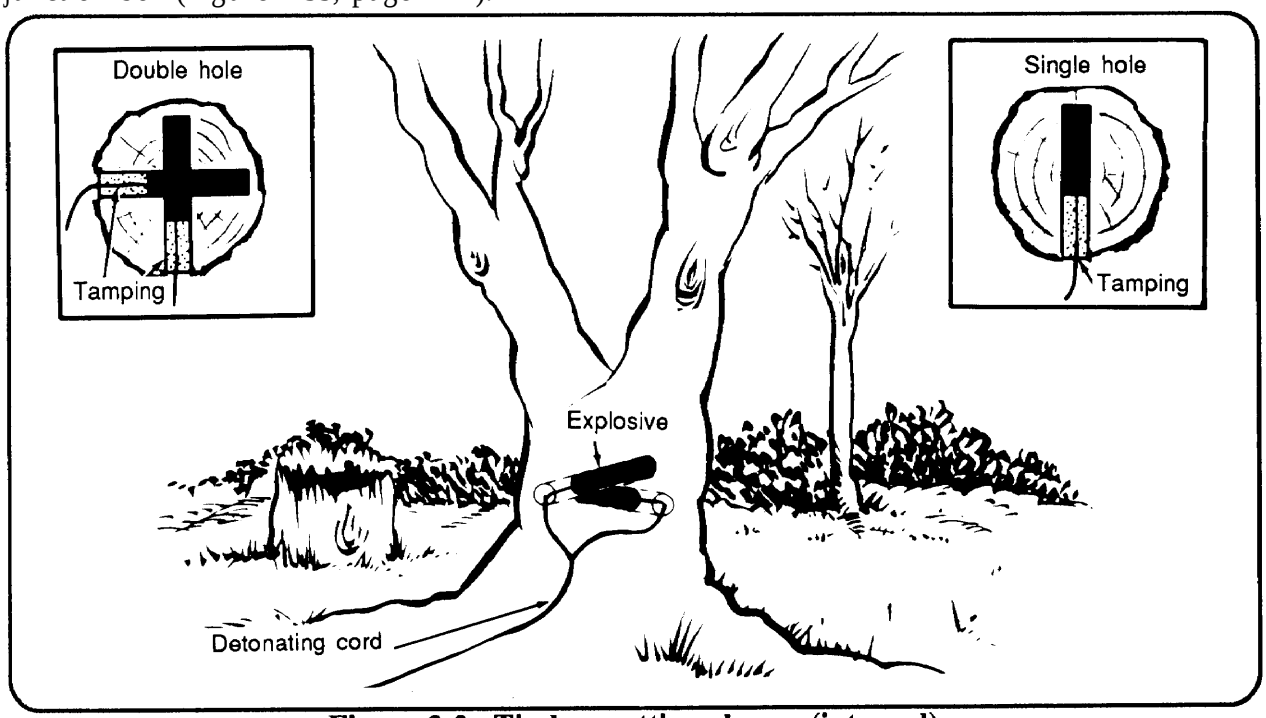


Figure 3-2. Timber-cutting charge (internal)

b. *External Charges.* To be most effective, external charges should be rectangular, 1 to 2 inches thick, and twice as wide as they are high. Remove the bark to place the explosive indirect contact with solid wood and to reduce air gaps between the charge and the wood. If the timber is not round or if the direction of fall is not important, place the explosive on the widest face. Doing this will concentrate the force of the blast through the least dimension of the timber. Trees will fall toward the side on which the explosive is placed, unless influenced by wind or lean of the tree (Figure 3-3). If the tree is leaning the wrong way or a strong wind is blowing, place a l-pound *kicker* charge on the side opposite the main charge, about two-thirds of the way up the tree. Fire the kicker charge at the same time as the main charge. For best results when using C4, orient the charge's longest dimension horizontally. Orienting the charges vertically tends to allow gaps to develop between the charges. Example A-2

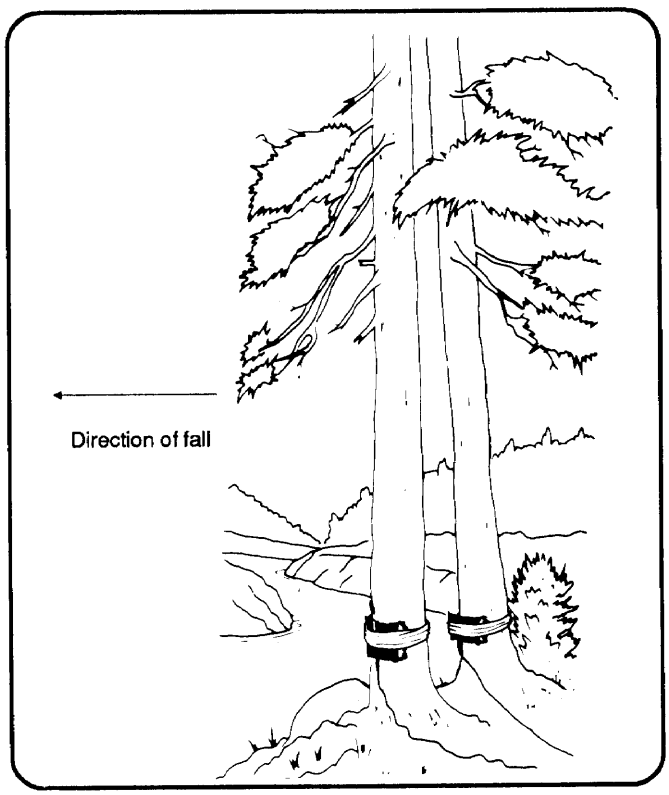


Figure 3-3. Timber-cutting charge (external)

(page A-2) shows how to calculate external timber-cutting charges. Use the following formula to determine the amount of explosive needed for cutting trees, posts, beams, or other timber, using untamped external charges:

$$P = \frac{D^2}{40} \text{ or } P = 0.025D^2 \quad \textbf{(3-2)}$$

where–

P = TNT required per target, in pounds.
D = diameter or least dimension of dimensioned timber, in inches.

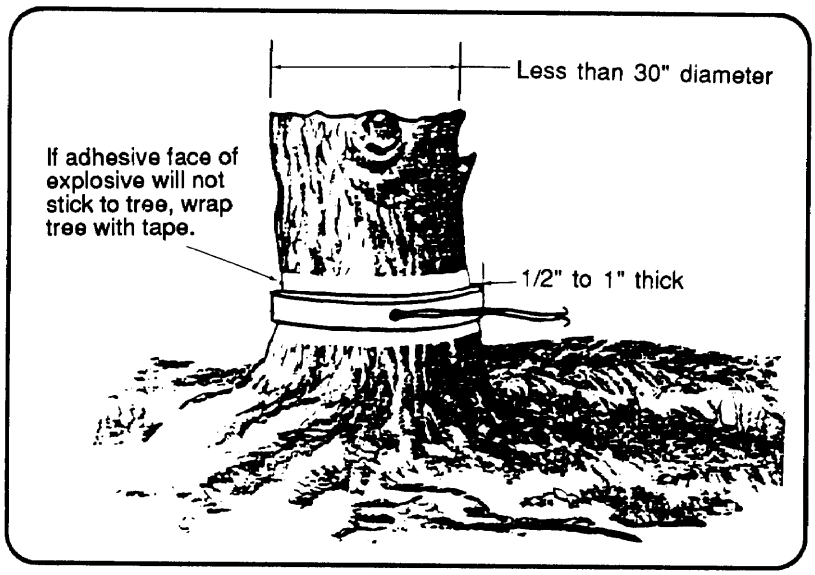


Figure 3-4. Timber-cutting ring charge

c. *Ring Charge.* The ring charge is a band of explosives completely circling the tree (Figure 3-4). The explosive band should be as wide as possible and at least 1/2 inch thick for small-diameter trees (up to 10 inches in diameter) and 1 inch thick for medium- and large-diameter trees (up to 30 inches in diameter). Use this technique when stump elimination is important and the direction of fall is not. For example, removing stumps would be important when clearing timber for a helicopter landing zone. Determine the amount of explosive necessary by using the external-charge formula. Prime the ring charge in two opposing places with branch lines. Connect the branch lines in a junction box (Figure 2-35, page 2-27).

d. *Underwater Charge.* To cut a timber pile underwater, use a method similar to the one illustrated in Figure 3-5. Determine the size of the charge using the external-charge formula. Place the charge on the upstream side of the pile and as deep as possible. The stream flow on this part of the pile will maximize the tamping effect on the explosive.

e. *Abatis.* Fallen-tree obstacles (Figure 3-6) are made by cutting trees that remain attached to their stumps. Since trees vary in their physical properties, a test shot is required. Use the following formula to compute the amount of TNT required for the test shot:

$$P = \frac{D^2}{50} \text{ or } P = 0.02D^2 \quad \textbf{(3-3)}$$

where—

P = TNT required per tree, in pounds.
D = diameter or least dimension of dimensioned timber, in inches.

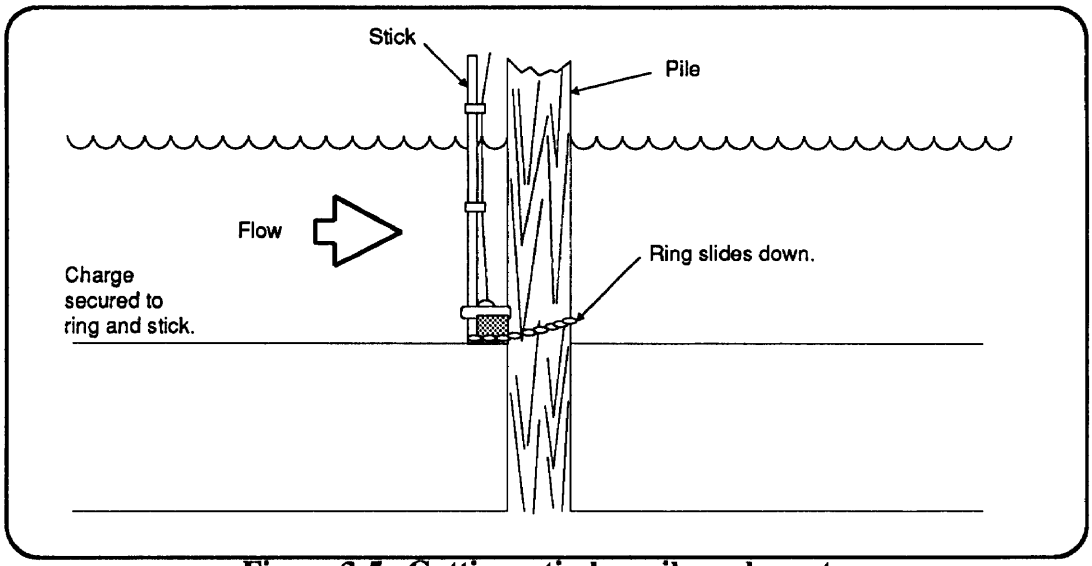


Figure 3-5. Cutting a timber pile underwater

(1) Placement. Place abatis charges in the same way as external timber charges except place the charges 5 feet above ground level. The tree will fall toward the side where the explosive is attached unless influenced by the lean of the tree or wind.

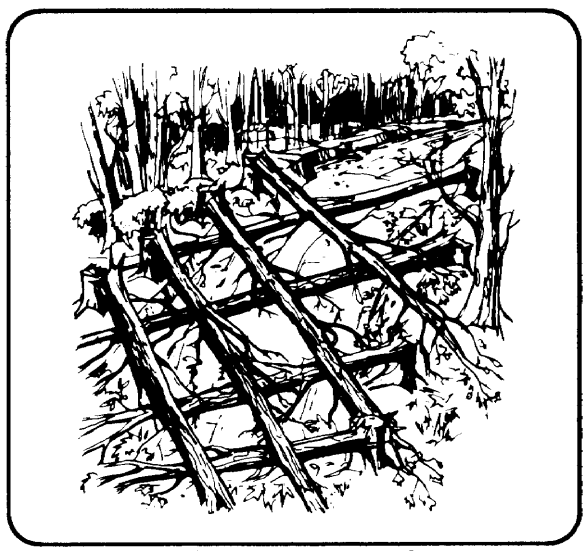


Figure 3-6. Abatis

(2) Special Considerations. Consider the following when creating an abatis:

- Make sure the obstacle will cover at least 75 meters from end to end.
- Make sure the individual trees are at least 24 inches in diameter. Smaller trees are not effective obstacles against tracked vehicles.
- Fell trees 3 to 4 meters apart. Doing this creates a condition that prevents tracked vehicles from driving over the top of the obstacle.
- Fell the trees at a 45-degree angle toward the enemy.
- Simultaneously detonate the charges on the trees on one side of the road at a time. Then, fell the trees on the other side of the road. Delay blasting of the trees on the other side of the road until the frost trees have completely fallen.
- To make obstacles harder to remove, place mines, booby traps, or barbed or concertina wire in the obstacle, and cover the obstacle with director indirect fire.

f. *Hasty Timber Calculations.* Table 3-1 (page 3-8) lists the required number of C4 packages for cutting timber with internal, external, and abatis charges.

Table 3-1. Timber-cutting charge size

Charge Type	Packages of Composition C4 Required (1.25-Pound Packages) by Timber Diameter (Inches)											
	6	8	10	12	15	18	21	24	27	30	33	36
Internal	1	1	1	1	1	1	2	2	2	3	3	4
External	1	1	2	3	4	5	7	9	11	14	17	20
Abatis	—	—	—	—	—	—	—	7	9	11	13	16
NOTE: Packages required are rounded UP to the next whole package.												

3-6. Steel-Cutting Charges.

WARNING
Steel-cutting charges produce metal fragments. Proper precautions should be taken to protect personnel. Refer to Table 6-3, page 6-7.

a. *Target Factors.* The following target factors are critical in steel-structure demolitions, more so than with other materials:

(1) Target Configuration. The configuration of the steel in the structure determines the type and amount of charge necessary for successful demolition. Examples of structured steel are I-beams, wide-flange beams, channels, angle sections, structural tees, and steel plates used in building or bridge construction. Example A-3 (page A-3) shows how to calculate steel-cutting charges for wide-flange beams and girders.

(2) Target Materials. In addition to its configuration, steel also has varied composition:

(a) High-carbon steel. Metal-working dies and rolls are normally composed of high-carbon steel and are very dense.

(b) Alloy steel. Gears, shafts, tools, and plowshares are usually composed of alloy steel. Chains and cables are often made from alloy steel; however, some chains and cables are composed of high-carbon steel. Alloy steel is not as dense as high-carbon steel.

(c) Cast iron. Some steel components (such as railroad rails and pipes) are composed of cast iron. Cast iron is very brittle and easily broken.

(d) Nickel-molybdenum steel. This type of steel cannot be cut easily by conventional steel-cutting charges. The jet from a shaped charge will penetrate it, but cutting requires multiple charges or linear-shaped charges. Nickel-molybdenum steel shafts can be cut with a diamond charge. However, the saddle charge will not cut nickel-molybdenum shafts. Therefore, use some method other than explosives to cut nickel-molybdenum steel, such as thermite or acetylene or electrical cutting tools.

b. *Explosives Factors.* In steel-cutting charges, the type, placement, and size of the explosive are important. Confining or tamping the charge is rarely practical or possible. The following factors are important when selecting steel-cutting charges:

(1) Type. Select steel-cutting charges that operate with a cutting effect. Percussive charges are not very effective for steel cutting. Plastic explosive (C4) and sheet explosive (Ml 18) are best. These explosives have very effective cutting power and are easily cut and shaped to fit tightly into the grooves and angles of the target. These explosives are particularly effective when demolishing structural steel, chains, and steel cables.

(2) Placement (Figure 3-7). To achieve the most effective initiation and results, ensure that—

- The charge is continuous over the complete line of the proposed cut.
- There is close contact between the charge and the target.
- The width of the charge's cross section is between one and three times its thickness. Do not use charges more than 6 inches thick because you can achieve better results by increasing the width rather than the thickness.
- Long charges are primed every 4 to 5 feet. If butting C4 packages end to end along the line of the cut, prime every fourth package.
- The direction of initiation is perpendicular to the target (Figure 3-1, page 3-3).

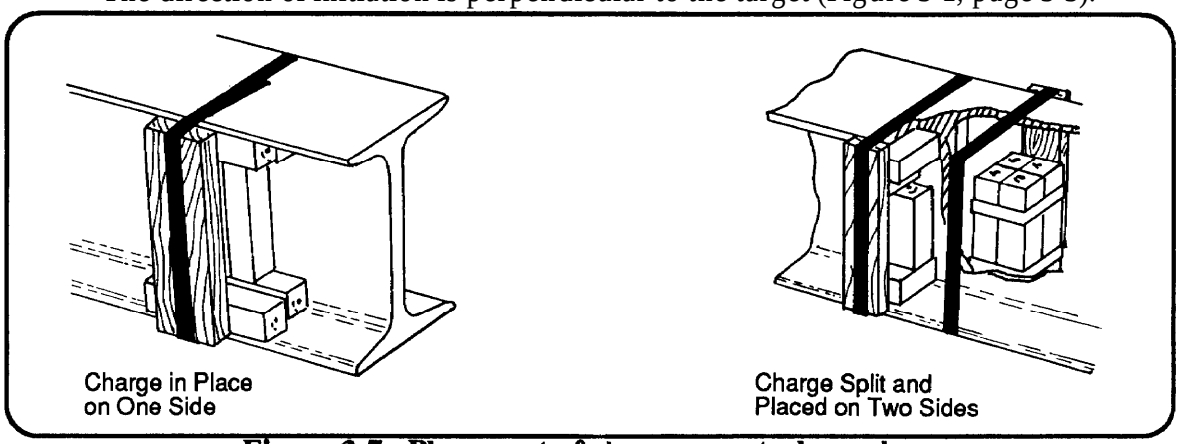


Figure 3-7. Placement of charges on steel members

(3) Size. The size of the charge is dictated by the target steel's type and size and the type of charge selected. Use either C4 or TNT block explosives for cutting steel. C4 works best. Each steel configuration requires a unique charge size.

(a) Block charge. Generally, the following formula will give you the size of charge necessary for cutting I-beams, built-up girders, steel plates, columns, and other structural steel sections. (When calculating cutting charges for steel beams, the area for the top flange, web, and bottom flange must be calculated separately.) Built-up beams also have rivet heads and angles or welds joining the flanges to the web. You must add the thickness of one rivet head and the angle iron to the flange thickness when determining the thickness of a built-up beam's flange. Use the thinnest point of the web as the web thickness, ignoring rivet-head and angle-iron thickness. Cut the lattice of lattice-girder webs diagonally by placing a charge on each lattice along the line of the cut. Use Tables 3-2 and 3-3 (page 3-10) to determine the correct amount of C4 necessary for cutting steel sections. Use the following formula to determine the required charge size (Table 3-3, page 3-10, is based on this formula):

$$P = (\frac{3}{8})A \text{ or } P = 0.375A \quad (3\text{-}4)$$

where–

P = TM required, in pounds.
A = cross-sectional area of the steel member, in square inches.

Table 3-2. Hasty steel-cutting chart for TNT

Average Thickness of Section (in)	Pounds of explosive* for rectangular steel sections of given dimensions																
	Height of section (in)																
	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24
¼	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.3
⅜	0.3	0.5	0.6	0.7	0.9	1.1	1.2	1.3	1.4	1.6	1.7	2.0	2.3	2.6	2.8	3.1	3.4
½	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.7	3.0	3.4	3.8	4.2	4.5
⅝	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	2.4	2.7	2.9	3.3	3.8	4.3	4.7	5.2	5.7
¾	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.1	3.4	4.0	4.5	5.1	5.7	6.3	6.8
⅞	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.0	3.3	3.7	4.0	4.6	5.3	6.0	6.6	7.3	7.9
1	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	5.3	6.0	6.8	7.5	8.3	9.0

*TNT

Table 3-3. Hasty steel-cutting chart for C4

Section Thickness (inches)	Weight of Composition C4 Required for Rectangular Steel Sections (Height or Width, in Inches)													
	2	3	4	5	6	8	10	12	14	16	18	20	22	24
1/4	0.2	0.3	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.5	1.6	1.8
3/8	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.1	2.4	2.6
1/2	0.3	0.5	0.6	0.8	0.9	1.2	1.5	1.8	2.1	2.3	2.6	2.9	3.2	3.4
5/8	0.4	0.6	0.8	0.9	1.1	1.5	1.8	2.2	2.5	2.9	3.2	3.5	3.9	4.3
3/4	0.5	0.7	0.9	1.1	1.3	1.8	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1
7/8	0.6	0.8	1.1	1.3	1.5	2.1	2.5	3.0	3.5	4	4.5	5.0	5.5	5.9
1	0.6	0.9	1.2	1.5	1.8	2.3	2.9	3.4	4.0	4.5	5.1	5.6	6.2	6.8

NOTE: Round UP to the nearest 1/10 pound when calculating charge sizes.

To use this table:
1. Measure each rectangular section of the total member separately.
2. Find the approparite charge size for the rectangular section from the table. If the section dimension is not listed in the table, use the next-larger dimension.
3. Add the individual charges for each section to obtain the total charge weight.

(b) High-carbon or alloy steel. Use the following formula to determine the required charge for cutting high-carbon or alloy steel:

$$P = D^2 \qquad (3\text{-}5)$$

where–

P = TNT required, in pounds.
D = diameter or thickness of section to be cut, in inches.

(c) Steel bars, rods, chains, and cables (up to 2 inches). The size of these materials makes proper charge placement difficult. For example, Figure 3-8 shows charge placement on a chain. If the explosive is long enough to bridge both sides of the link or is large enough to fit snugly between the two links, use one charge. If the explosive is not large enough to bridge both sides, use two charges. Use the following amount of explosive:

- For materials up to 1 inch in diameter or thickness, use 1 pound of explosive.
- For materials between 1 and 2 inches in diameter or thickness, use 2 pounds of explosive.

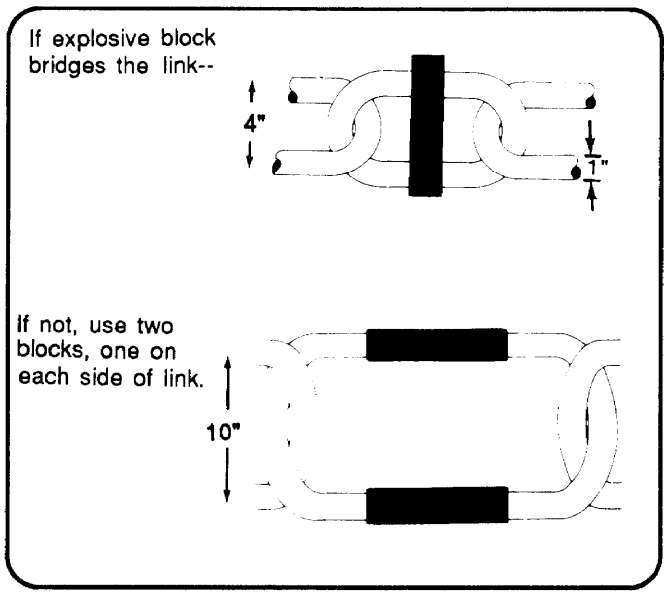


Figure 3-8. Charge placement on chains

(d) Steel bars, rods, chains, and cables (over 2 inches). When the target diameter or thickness is 2 inches or greater, use equation 3-4. When the thickness or diameter is 3 inches or greater, place half of the charge on each side of, the target and stagger the placement to produce the maximum shearing effect (Figure 3-9).

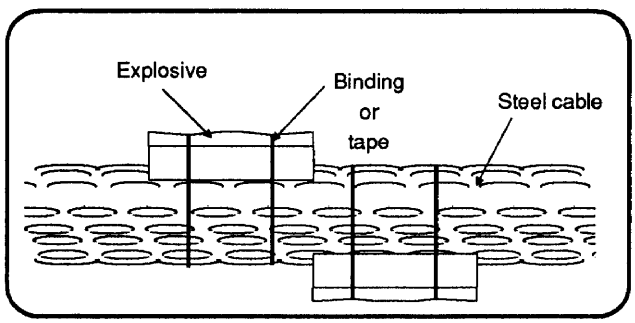


Figure 3-9. Charge placement on steel

(e) Railroad rails. The height of the railroad rail is the critical dimension for determining the amount of explosive required. For rails 5 inches or more in height, crossovers, and switches, use 1 pound of C4 or TNT. For rails less than 5 inches high, use 1/2 pound of C4 or TNT (Figure 3-10, page 3-12). Railroad frogs require 2 pounds of C4 or TNT. Place the charges at vulnerable points, such as frogs, curves, switches, and crossovers, if possible. Place the charges at alternate rail splices for a distance of 500 feet.

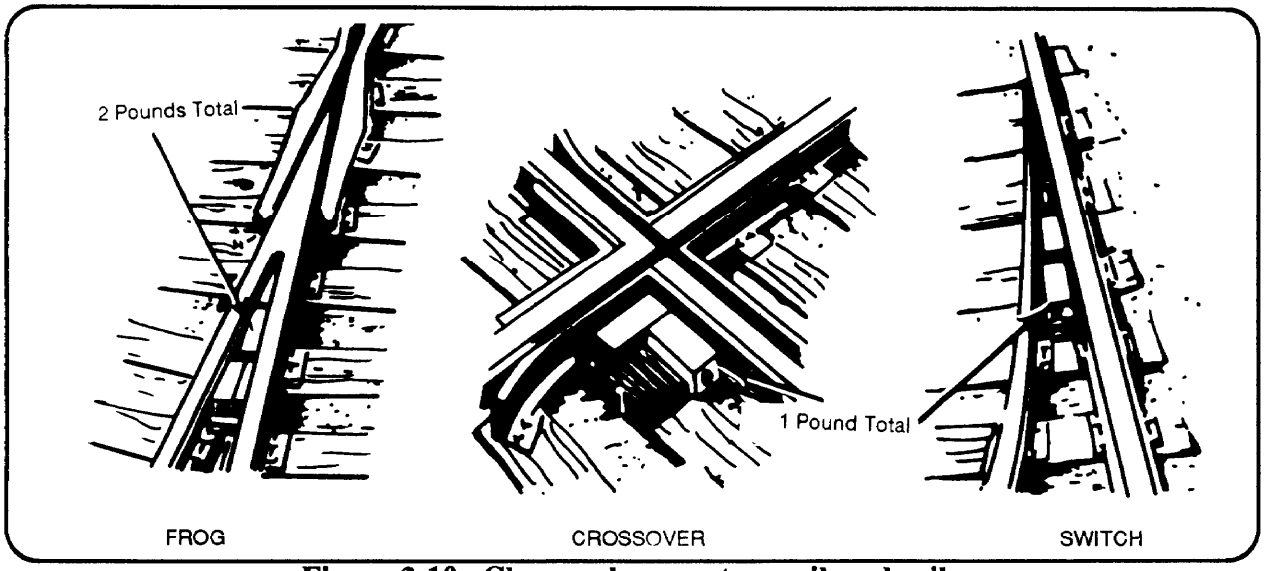


Figure 3-10. Charge placement on railroad rails

Section III. Special Cutting Charges

3-7. Purpose. When time and circumstances permit, you can use the special cutting charges (ribbon, saddle, and diamond charges) instead of conventional cutting charges. These charges may require extra time to prepare, since they require exact and careful target measurement to achieve optimal effect. With practice, an engineer can become proficient at calculating, preparing, and placing these charges in less time than required for traditional charges. Special cutting charges use considerably less explosive than conventional charges. Use plastic-explosive (M112) or sheet-explosive (Ml18 or Ml86) charges as special charges. C4 requires considerable cutting, shaping, and molding, which may reduce its density and, therefore, its effectiveness. Sheet explosive is more suitable than C4, since sheet explosive is more flexible and requires less cutting. Use of these charges requires considerable training and practice. The charges are thin and require blasting caps crimped to a detonating-cord branch line for initiation. (A detonating-cord knot will work but is difficult to place and can ruin the advantage of the special charge shape).

3-8. Ribbon Charges. Use these charges to cut flat, steel targets up to 3 inches thick (Figure 3- 11). Make the charge thickness one-half the target thickness but never less than 1/2 inch. Make the charge width three times the charge thickness and the length of the charge equal to the length of the desired cut. Detonate the ribbon charge from the center or from either end. When using the ribbon charge to cut structural steel sections, place the charge as shown in Figure 3-12. The detonating-cord branch lines must be the same length and must connect in a junction box (Figure 2-35, page 2-27). Example A-5 (page A-5) shows how to calculate steel-cutting charges for steel plates. The formula for the ribbon charge is as follows:

a. *Charge Thickness.* The charge thickness equals one half the target's thickness; however, it will never be less than 1/2 inch.

b. *Charge Width.* The charge width is three times charge thickness.

c. *Charge Length.* The charge length equals the length of the desired cut.

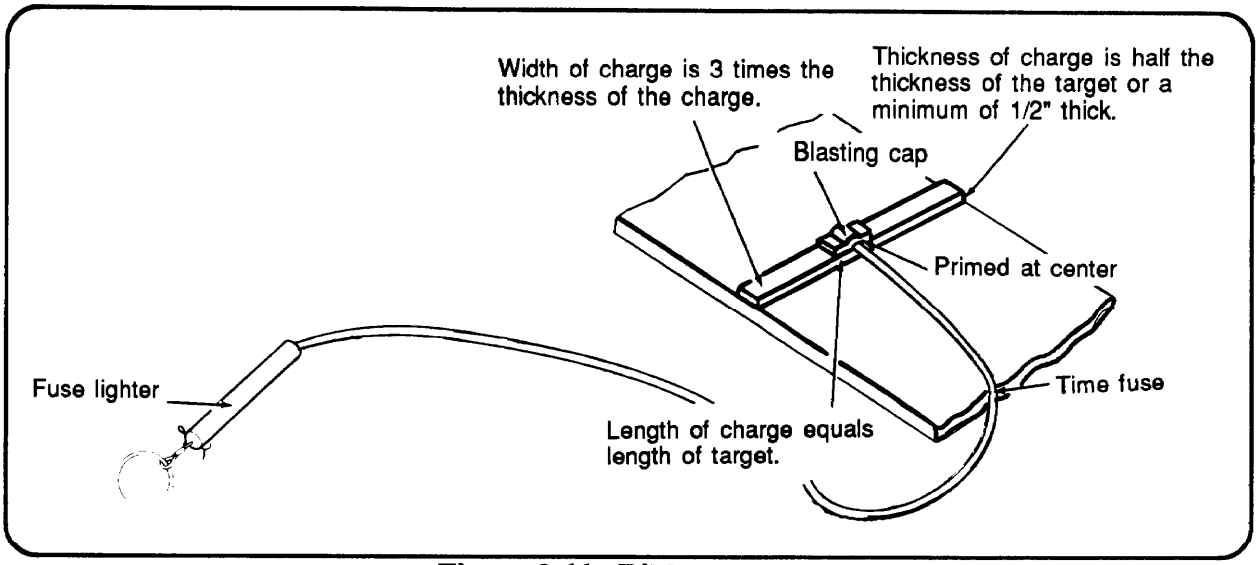

Width of charge is 3 times the thickness of the charge.
Thickness of charge is half the thickness of the target or a minimum of 1/2" thick.
Blasting cap
Primed at center
Time fuse
Fuse lighter
Length of charge equals length of target.

Figure 3-11. Ribbon charge

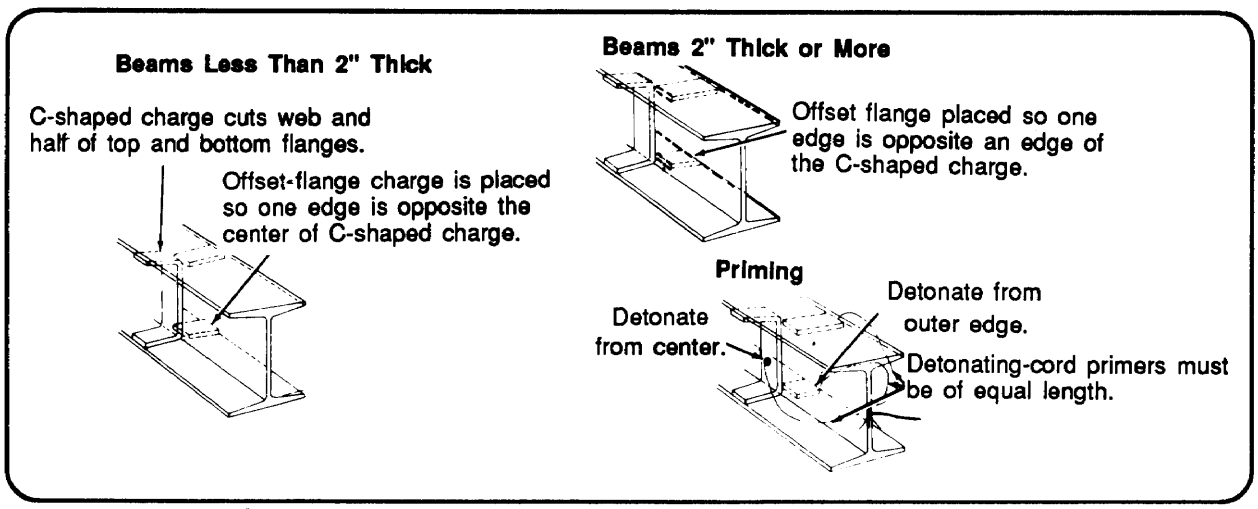

Beams Less Than 2" Thick
C-shaped charge cuts web and half of top and bottom flanges.
Offset-flange charge is placed so one edge is opposite the center of C-shaped charge.
Beams 2" Thick or More
Offset flange placed so one edge is opposite an edge of the C-shaped charge.
Priming
Detonate from center.
Detonate from outer edge.
Detonating-cord primers must be of equal length.

Figure 3-12. Placement of ribbon charge on structural steel

3-9. Saddle Charge. This steel-cutting method uses the destructive effect of the cross fracture formed in the steel by the base of the saddle charge (end opposite the point of initiation). Use this charge on mild steel bars, whether round, square, or rectangularly shaped, up to 8 square inches or 8 inches in diameter (Figure 3-13, page 3-14). Make the charge a uniform l-inch thick. Example A-7 (page A-7) shows how to calculate steel-cutting charges for steel bars, Determine the dimensions of the saddle charge as follows:

a. *Dimensions.*

(1) Thickness. Make the charge 1 inch thick (standard thickness of Ml 12 block explosive).

(2) Base Width. Make the base width equal to one-half the target circumference or perimeter.

(3) Long-Axis Length. Make the long-axis length equal to the target circumference or perimeter.

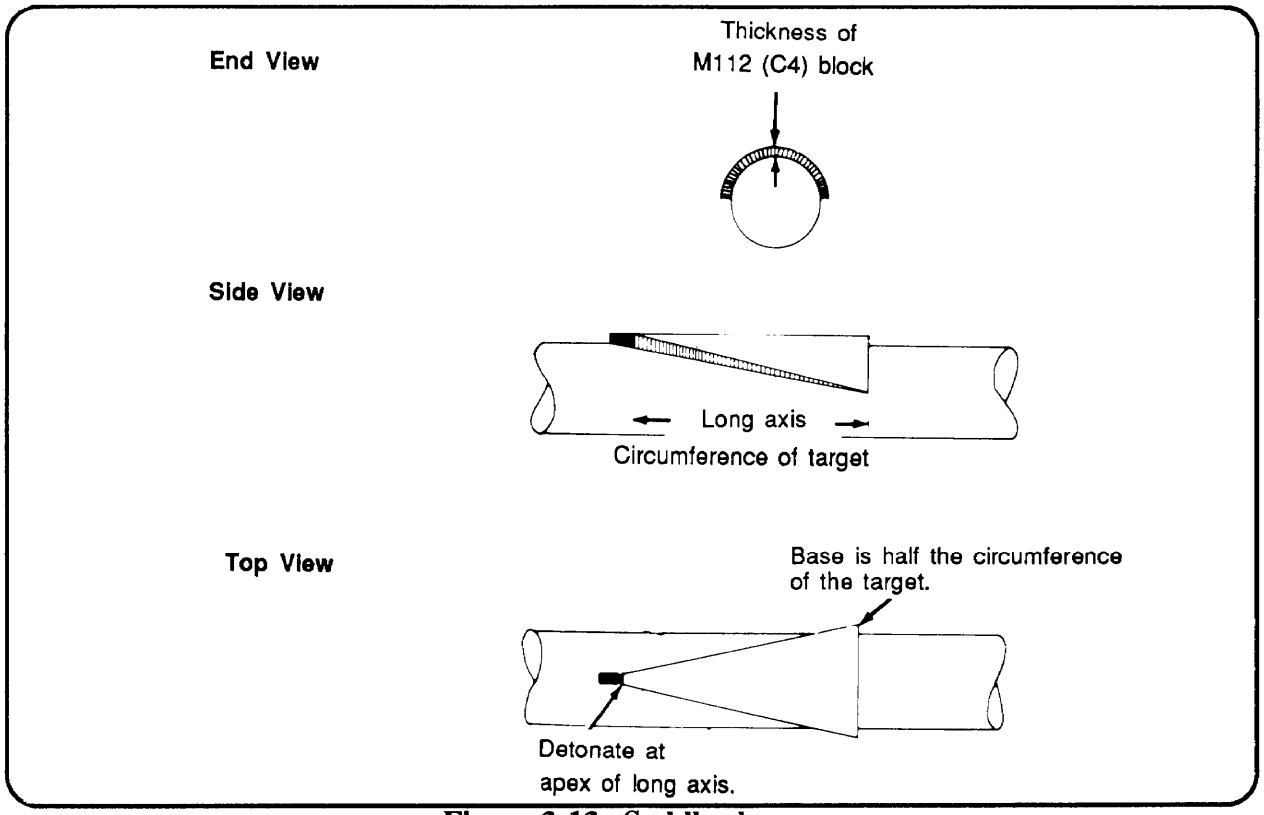


Figure 3-13. Saddle charge

b. *Detonation.* Detonate the saddle charge by placing a blasting cap at the apex of the long axis.

c. *Placement.* The long axis of the saddle charge should be parallel with the long axis of the target. Cut the charge to the correct shape and dimensions and then place it around the target. Ensure the charge maintains close contact with the target by taping the charge to the target.

3-10. Diamond Charge. This technique, the *stress-wave method,* employs the destructive effect of two colliding shock waves. The simultaneous detonation of the charge from opposite ends (Figure 3-14) produces the shock waves. Use the diamond charge on high-carbon or alloy steel bars up to 8 inches in diameter or having cross-sectional areas of 8 square inches or less. Example A-8 (page A-7) shows how to calculate steel-cutting charges for high-carbon steel.

a. *Dimensions.*

(1) Thickness. Make the charge 1 inch thick (standard thickness of Ml12 block explosive).

(2) Long-Axis Length. Make the long-axis length equal to the target circumference or perimeter.

(3) Short-Axis Length. Make the short-axis length equal to one-half the target circumference or perimeter.

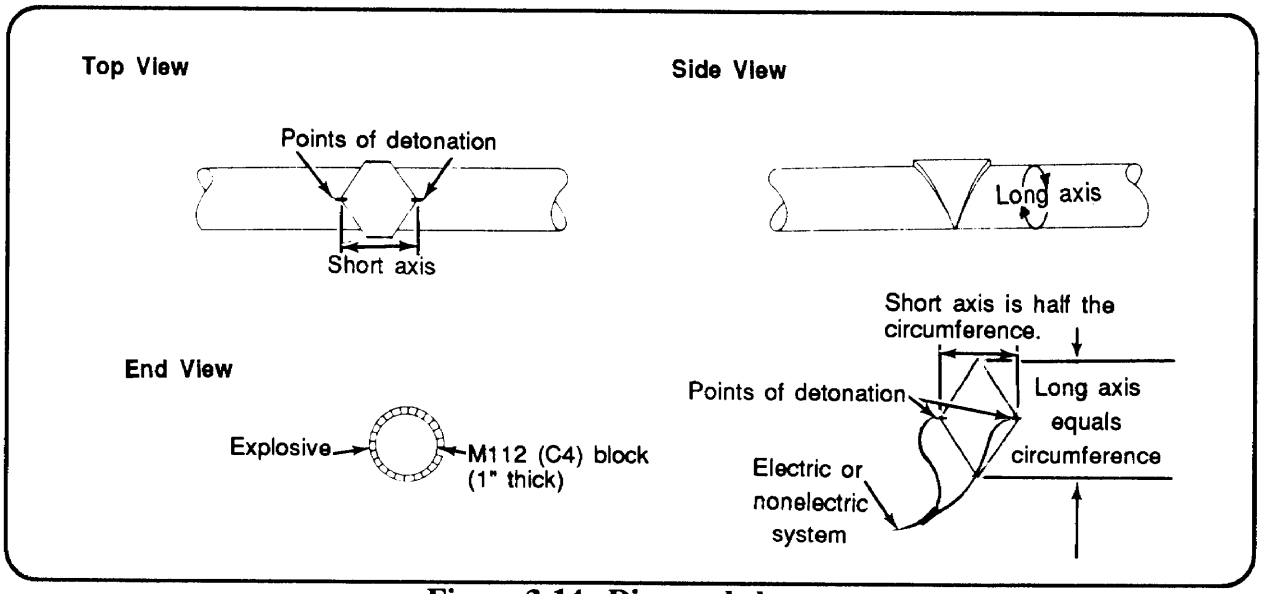


Figure 3-14. Diamond charge

b. *Placement.* Place the explosive completely around the target so that the ends of the long axes touch. You may have to slightly increase the charge dimensions to do this. To ensure adequate contact with the target, tape the charge to the target.

c. *Priming.* Prime the diamond charge (Figure 3-14) with two detonating cord branch lines using one of the following methods:

- Detonating cord knots (Figure 2-15, page 2- 14).
- Two electric blasting caps in a series circuit (Figure 2-7, page 2-8).
- Two nonelectric blasting caps (Figure 2-35, page 2-27).

NOTE: When using detonating cord knots or nonelectric blasting caps, the branch lines must be the same length.

Section IV. Breaching Charges

3-11. Critical Factors. Use breaching charges to destroy bridge piers, bridge abutments, and permanent field fortifications. The size, shape, placement, and tamping or confinement of breaching charges are critical to success. The size and confinement of the explosive are the most critical factors because the targets are usually very strong and bulky. The intent of breaching charges is to produce and transmit sufficient energy to the target to make a crater and create spalling. Breaching charges placed against reinforced concrete will not cut metal reinforcing bars. Remove or cut the reinforcement with a steel-cutting charge after the concrete is breached.

3-12. Computation.

a. *Formula.* Determine the size of the charge required to breach concrete, masonry, rock, or similar material by using the following formula:

$$P = R^3KC \qquad (3\text{-}6)$$

where—

P = *TNT required, in pounds.*
R = *breaching radius, in feet.*
K = *material factor, which reflects the strength, hardness, and mass of the material to be demolished, (Table 3-4).*
C = *tamping factor, which depends on the location and tamping of the charge (Figure 3-15).*

Table 3-4. Material factor (*K*) for breaching charges

Material	Breaching Radius (*R*)	*K*
Earth	All values	0.07
Poor masonry, Shale, Hardpan, Good timber, Earth construction	Less than 1.5 m (5 ft) 1.5 m (5 ft) or more	0.32 0.29
Good masonry, Concrete block, Rock	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 ft) 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	0.88 0.48 0.40 0.32 0.27
Dense concrete, First-class masonry	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 ft) 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	1.14 0.62 0.52 0.41 0.35
Reinforced concrete (Factor does not consider cutting concrete)	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 f)t 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	1.76 0.96 0.80 0.63 0.54

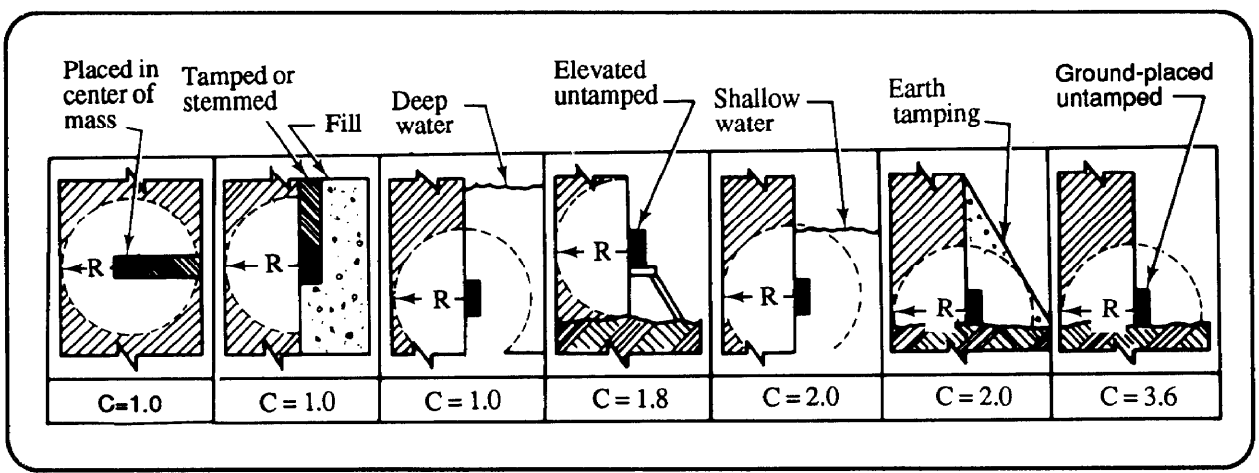


Figure 3-15. Tamping factor (*C*) for breaching charges

b. *Breaching Radius (R).* The breaching radius for external charges is equal to the thickness of the target being breached. For internal charges placed in the center of the target's mass, the breaching radius is one half the thickness of the target. If the charge is placed at less than half the mass thickness, the breaching radius is the longer of the distances from the center of the charge to the outside surfaces of the target. For example, when breaching a 4-foot wall with an internal charge placed 1 foot into the wall, the breaching radius is 3 feet (the longest distance from the center of the explosive to an outside target surface). If placed at the center of the wall's mass, the explosive's breaching radius is 2 feet (one-half the thickness of the target). The breaching radius is 4 feet for an external charge on this wall. Round values of R to the next-higher ¼-foot distance for internal charges and to the next-higher ½-foot distance for external charges.

c. *Material Factor (K).* K represents the strength and hardness of the target material. Table 3-4 gives values for K for various types and thicknesses of material. When you are unable to positively identify the target material, assume the target consists of the strongest type of material in the general group. Always assume concrete is reinforced and masonry is first-class unless you know the exact condition and construction of the target materials.

d. *Tamping Factor (C).* C depends on the charge location and materials used for tamping. Figure 3-15 illustrates methods for placing charges and gives the values of C for both tamped and untamped charges. When selecting a value for C from Figure 3-15, do not consider a charge tamped with a solid material (such as sand or earth) as fully tamped unless you cover the charge to a depth equal to or greater than the breaching radius.

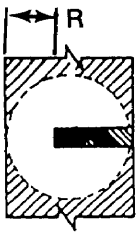
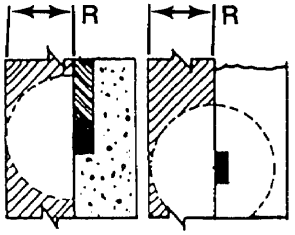
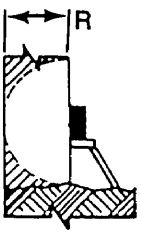
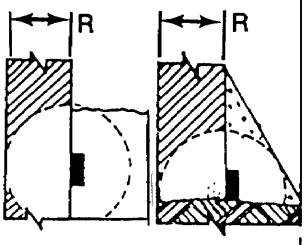
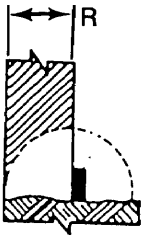
3-13. Breaching Reinforced Concrete. Table 3-5 (page 3-18) gives the number of C4 packages required for breaching reinforced-concrete targets. Example A-9 (page A-8) shows how to calculate the breaching charge for a reinforced-concrete pier. The amounts of C4 in the table are based on equation 3-6. To use the table, do the following:

a. Measure the concrete thickness.

b. Decide how the charge will be placed against the target. Compare the method of placement with the diagrams at the top of the Table 3-5 (page 3-18). If in doubt about which column to use, always use the column that lists the greatest amount of explosive.

c. Using the column directly under the chosen placement method, select the amount of explosive required, based on target thickness. For example, 200 packages of C4 are required to breach a 7-foot reinforced-concrete wall with an untamped charge placed 7 feet above ground.

Table 3-5. Breaching charges for reinforced concrete

Concrete Thickness (Feet)	Placement Methods				
					
	C = 1.0	C = 1.0	C = 1.8	C = 2.0	C = 3.6
	Packages of M112 (Composition C4)				
2.0	1	5	9	10	17
2.5	2	9	17	18	33
3.0	2	13	24	26	47
3.5	4	21	37	41	74
4.0	5	31	56	62	111
4.5	7	44	79	88	157
5.0	9	48	85	95	170
5.5	12	63	113	126	226
6.0	13	82	147	163	293
6.5	17	104	186	207	372
7.0	21	111	200	222	399
7.5	26	137	245	273	490
8.0	31	166	298	331	595

NOTE: The results of all calculations for this table have been rounded UP to the next whole package.

3-14. Breaching Other Materials. You can also use Table 3-5 to determine the amount of C4 required for other materials by multiplying the value from the table by the proper conversion factor from Table 3-6. Use the following procedure:

a. Determine the type of material in the target. If in doubt, assume the material to be the strongest type from the same category.

b. Determine from Table 3-5 the amount of explosive required if the object were made of reinforced concrete.

c. Find the appropriate conversion factor from Table 3-6.

d. Multiply the number of packages of explosive required (from Table 3-5) by the conversion factor (from Table 3-6).

Table 3-6. Conversion factors for material other than reinforced concrete

Material	Conversion Factor
Earth	0.1
Ordinary masonry Hardpan Shale Ordinary concrete Rock Good timber Earth construction	0.5
Dense concrete First-class masonry	0.7

3-15. Number and Placement of Charges.

a. *Number of Charges.* Use the following formula for determining the number of charges required for demolishing piers, slabs, or walls:

$$N = \frac{W}{2R} \qquad (3\text{-}7)$$

where–

N = *number of charges. (If N is less than 1.25, use one charge; if N is 1.25 but less than 2.5, use two charges; if N is equal to or greater than 2.5, round to the nearest whole number and use that many charges.)*
W = *pier, slab, or wall width, in feet.*
R = *breaching radius, in feet.*

The first charge is placed R distance in from one side of the target. The remainder of the charges are spaced at a distance of 2R apart (Figure 3-16).

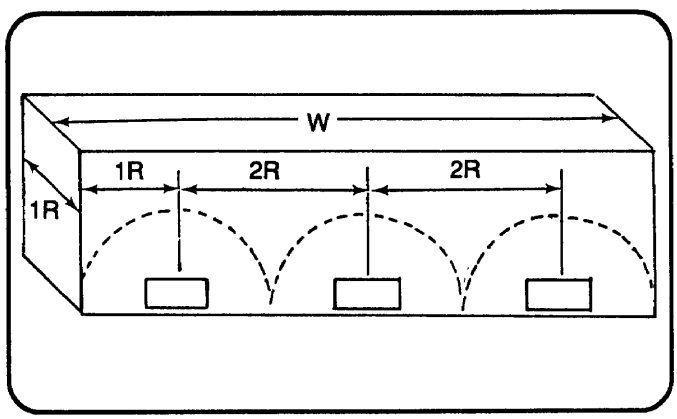


Figure 3-16. Charge placement

b. *Placement.*

(1) Limitations. Piers and walls offer limited locations for placing explosives. Unless a demolition chamber is available, place the charge (or charges) against one face of the target. Placing a charge above ground level is more effective than placing one directly on the ground. When the demolition requires several charges to destroy a pier, slab, or wall and you plan to use elevated charges, distribute the charges equally, no less than one breaching radius high from the base of the target. Doing this takes maximum advantage of the shock wave. If possible, place breaching charges so that there is a free reflection surface on the opposite side of the target. This free reflection surface

allows spalling to occur. If time permits, tamp all charges thoroughly with soil or filled sandbags. The tamped area must be equal to or greater than the breaching radius. For piers, slabs, or walls partially submerged in water, place charges equal to or greater than the breaching radius below the water line, if possible (Figure 3-15, page 3-16).

(2) Configuration. For maximum effectiveness, place the explosive charge in the shape of a flat square. The charge width should be approximately three times the charge thickness. The thickness of the charge depends on the amount of explosive required (Table 3-7).

Table 3-7. Breaching charge thickness*

Charge Weight (Pounds)	Charge Thickness (Inches)
Less than 5	1
5 to less than 40	2
40 to less than 300	4
300 or more	8
*Approximate values	

3-16. Counterforce Charge.

a. *Use.* This special breaching technique is effective against rectangular masonry or concrete columns 4 feet thick or less. It is not effective against walls, piers, or long obstacles. The obstacle also must have at least three free faces or be freestanding. If constructed of plastic explosives (C4) and properly placed and detonated, counterforce charges produce excellent results with a relatively small amount of explosive. Their effectiveness results from the simultaneous detonation of two charges placed directly opposite each other and as near the center of the target as possible (Figure 3-17).

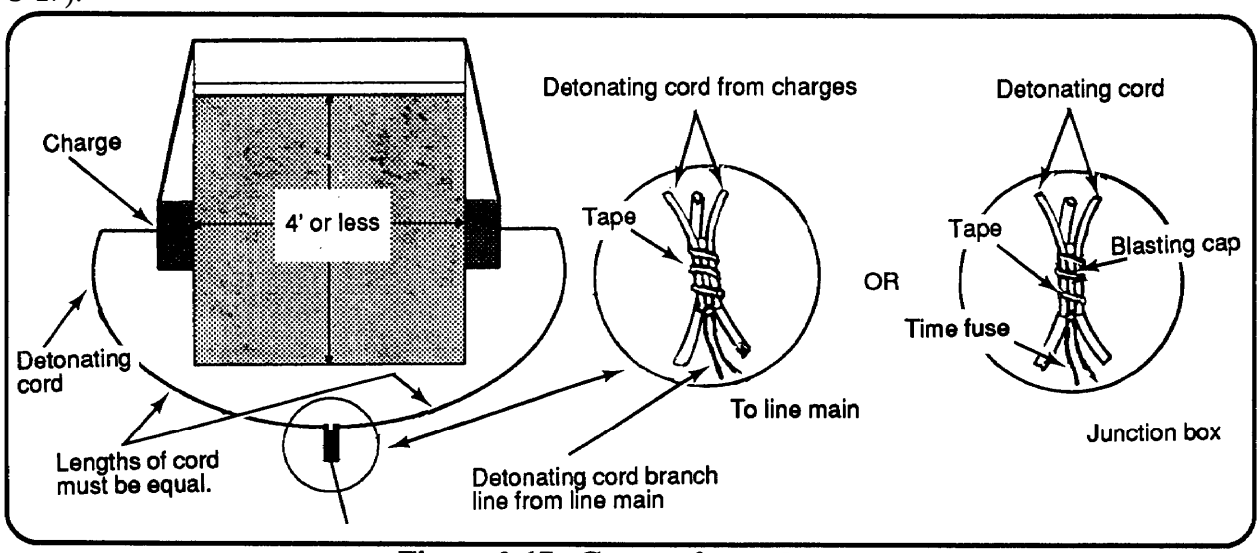


Figure 3-17. Counterforce charge

b. *Calculation.* The thickness or diameter of the target determines the amount of plastic explosive required. The amount of plastic explosive equals 1½ times the thickness of the target, in feet (1 ½ pounds of explosive per feet). Round fractional measurements to the next higher half foot

before multiplying. For example, a concrete target measuring 3 feet 9 inches thick requires 6 pounds of plastic explosive (1.5 lb / foot x 4 feet).

c. *Placement.* Split the charge in half. Place the two halves directly opposite each other on the target. This method requires accessibility to both sides of the target so the charges will fit flush against their respective target sides.

d. *Priming.* Prime both charges on the face farthest from the target. Join the ends of the detonating-cord branch lines in a junction box (Figure 3- 17). The length of the branch lines from both charges must be equal to ensure simultaneous detonation.

Section V. Cratering and Ditching Charges

3-17. Factors.

a. *Sizes.* To be effective obstacles, road craters must be too wide for track vehicles to span and too deep and steep-sided for any vehicle to pass through. Blasted road craters will not stop modern tanks indefinitely. A tank, making repeated attempts to traverse the crater, will pull soil loose from the slopes of the crater, filling the bottom and reducing both the crater's depth and angle of slope. Road craters are effective antitank obstacles if a tank requires three or more passes to traverse the crater, thereby providing enough time for antitank weapons to stop the tank. Road craters should be large enough to tie into natural or constructed obstacles at each end. Improve the effectiveness of blasted road craters by placing log hurdles on either side, digging the face of the hurdle vertically on the friendly side, mining the site with antitank and antipersonnel mines, filling the crater with water, or by using other means to further delay enemy armor. Cut road craters across the desired gap at a 45-degree angle from the direction of approach. This angled cut will increase the tank's tendency to slip sideways and ride off its track. To achieve sufficient obstacle depth, place craters in multiple or single rows, enhancing some other obstacle, such as a bridge demolition. When creating more than one row of craters, space them far enough apart so that a single armored vehicle launch bridge (AVLB) will not span them.

b. *Explosives.* All military explosives can create antitank craters. When available, use the 40-pound, ammonium-nitrate cratering charge (Figure 1-5, page 1-8) for blasting craters.

c. *Charge Confinement.* Place cratering charges in boreholes and tamp them.

3-18. Breaching Hard-Surfaced Pavements. Breach hard-surfaced pavements so that holes can be dug for the cratering charges. This can be done by exploding tamped charges on the pavement surface. Use a l-pound charge of explosive for each 2 inches of pavement thickness. Tamp the charges twice as deep as the pavement thickness. Shaped charges also are effective for breaching hard-surfaced pavements. A shaped charge will readily blast a small-diameter borehole through the pavement and into the subgrade. Blasting the boreholes with shaped charges will speed up the cratering task by first, eliminating the need to breach the pavement with explosive charges and then digging the hole for the cratering charge. Do not breach concrete at an expansion joint because the concrete will shatter irregularly. Table 1-3 (page 1-10) lists hole depths and optimum standoff distances when using the 15- or 40-pound shaped charges against various types of material, Shaped charges do not always produce open boreholes capable of accepting a 7-inch diameter cratering charge. You may need to remove some earth or widen narrow areas to accommodate the cratering

charge. Widen deep, narrow boreholes by knocking material from the constricted areas with a pole or rod or by breaking off the shattered concrete on the surface with a pick or crowbar.

3-19. Hasty Crater. This method takes the least amount of time to construct, based upon the number and depth of the boreholes. However, it produces the least effective barrier because of its depth and shape (Figure 3-1 8). The hasty method forms a V-shaped crater about 6 to 7 feet deep and 20 to 25 feet wide, extending approximately 8 feet beyond each end borehole. The sides of the crater slope 25 to 35 degrees. Modern US tanks require an average of four attempts to breach a hasty crater. To forma crater that is effective against tanks, boreholes must be at least 5 feet deep with at least 50 pounds of explosive in each hole. Use the following procedure to create a road crater:

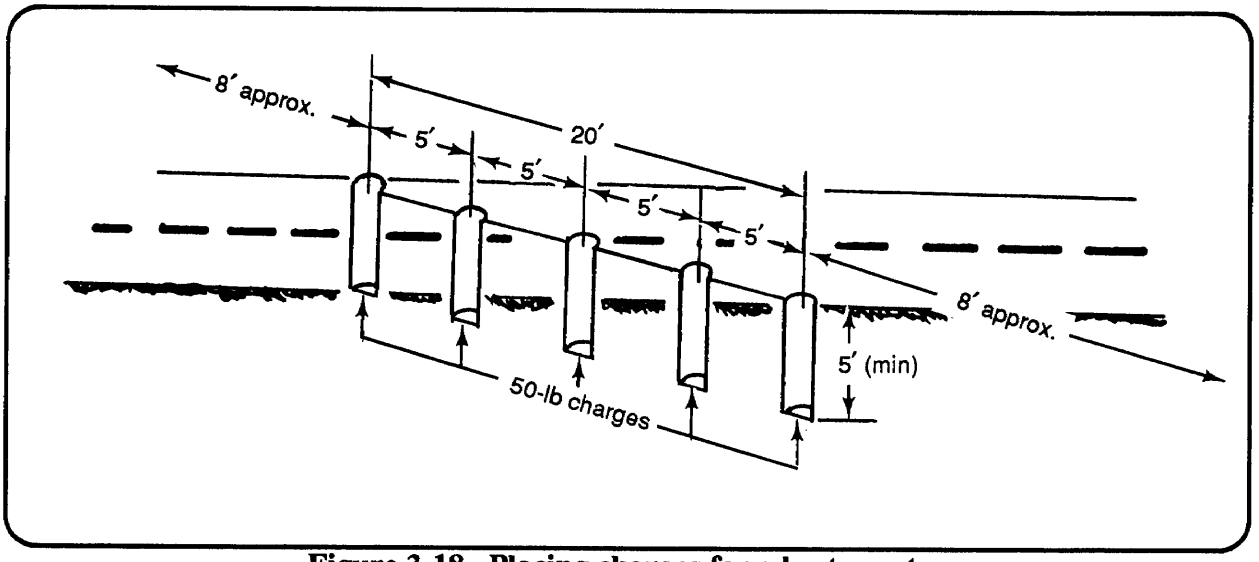


Figure 3-18. Placing charges for a hasty crater

a. *Boreholes.* Dig all boreholes to the same depth (5 feet or deeper recommended). Space the boreholes at 5-foot intervals, center to center, across the road. Use the following formula to compute the number of boreholes:

$$N = \frac{L - 16}{5} + 1 \qquad \textbf{(3-8)}$$

where–

N = *number of boreholes; round fractional numbers to next higher whole number.*
L = *length of the crater, in feet. (Measure across the area to be cut. Round fractional measurements to the next higher foot).*
16 = *combined blowout of 8 feet each side.*
5 = *5-foot spacing.*
1 = *factor to convert from spaces to holes.*

b. *Charge Size.* Load the boreholes with 10 pounds of explosive per foot of borehole depth. When using standard cratering charges, supplement each charge with additional explosives to obtain the required amount. For example, a 6-foot hole would require one 40-pound cratering charge and 20 pounds of TNT or C4.

c. *Firing System.* Use dual firing systems when time and explosives permit (Figures 2-27, page 2-24). Initiate with either electric or nonelectric caps. Dual prime the 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

d. *Tamping.* Tamp all boreholes with suitable materials.

3-20. Deliberate Crater. Figure 3-19 illustrates a method that produces a more effective crater than the hasty method. Modem US tanks require an average of eight attempts to breach a deliberate crater. Placing charges deliberately produces a V-shaped crater, approximately 7 to 8 feet deep and 25 to 30 feet wide, with side slopes of 30 to 37 degrees. The crater extends approximately 8 feet beyond the end boreholes. Example A-11 (page A-9) shows how to calculate a cratering charge.

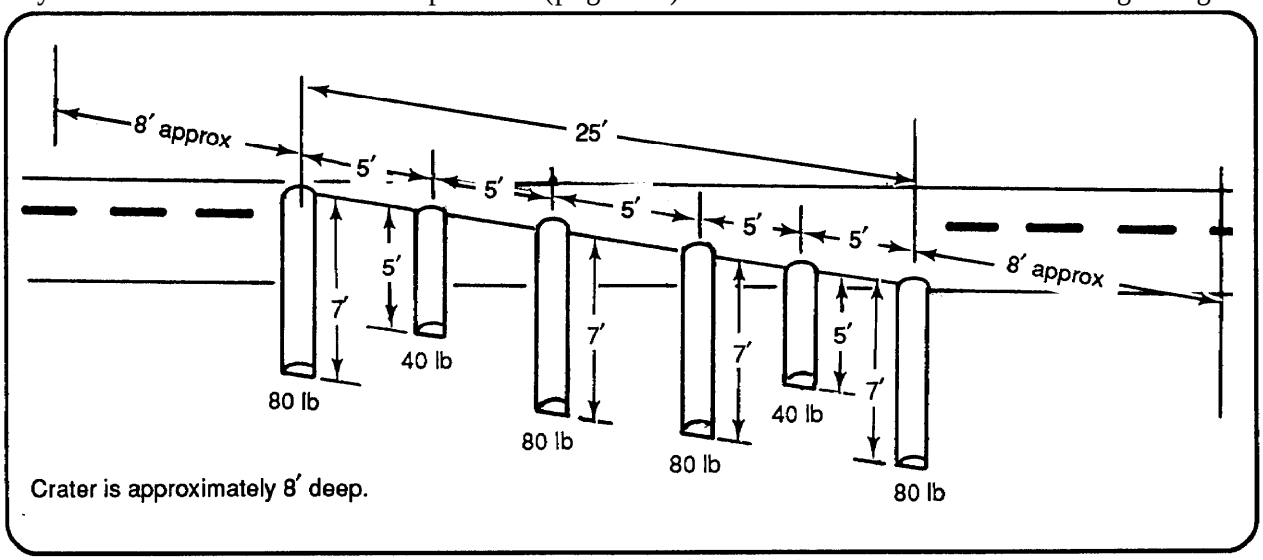


Figure 3-19. Placing charges for a deliberate crater

a. Determine the number of boreholes required, using the same formula as for a hasty crater. When there is an even number of holes (Figure 3-20, page 3-24), place two adjacent 7-foot boreholes in the middle.

b. Dig or blast the boreholes 5 feet apart, center to center, in a line across the area to be cut. Make the end boreholes 7 feet deep and the other boreholes alternately 5 and 7 feet deep. Never place two 5-foot holes next to each other.

c. Place 80 pounds of explosive in the 7-foot holes and 40 pounds of explosive in the 5-foot holes.

d. Use dual firing systems (Figure 2-27, page 2-24). Initiate with either electric or nonelectric caps. Dual prime the 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

e. Tamp all charges with suitable materials.

3-21. Relieved-Face Crater. The method shown in Figure 3-20 (page 3-24) produces a crater that is a more effective obstacle to modern tanks than the standard V-shaped crater. This technique produces a trapezoidal-shaped crater about 7 to 8 feet deep and 25 to 30 feet wide with unequal side slopes. In compact soil, such as clay, the relieved-face cratering method will create an obstacle such as the one illustrated in Figure 3-20 (page 3-24). The side nearest the enemy slopes approximately

25 degrees from road surface to crater bottom. The opposite (friendly) side slopes approximately 30 to 40 degrees from road surface to crater bottom. However, the exact shape of the crater depends on the type of soil. Use the following procedure to create a relieved-face crater:

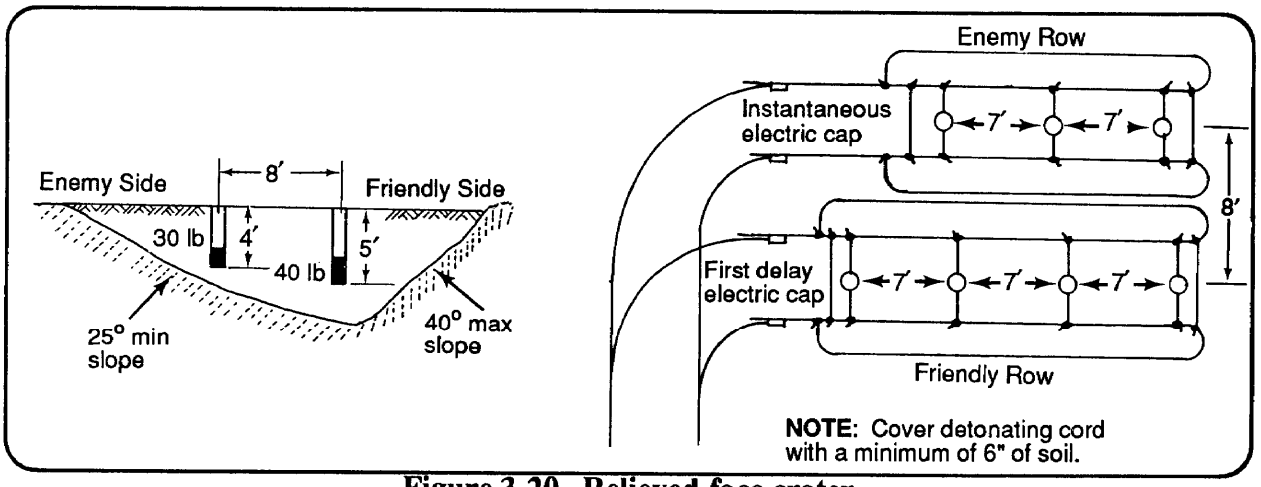


Figure 3-20. Relieved-face crater

a. On dirt or gravel-surfaced roads, drill two lines of boreholes 8 feet apart, spacing them at 7-foot centers. On hard-surfaced roads, drill the two lines of boreholes 12 feet apart. Use the following formula to compute the number of boreholes for the friendly-side row:

$$N = \frac{L - 10}{7} + 1 \qquad \textbf{(3-9)}$$

where—

N = *number of boreholes; round fractional numbers to the next higher whole number.*
L = *crater length, in feet. (Measure across the area to be cut. Round fractional measurements to the next higher foot.)*
10 = *combined blowout of 5 feet each side.*
7 = *spacing of holes.*
1 = *factor to convert spaces to holes.*

b. Stagger the boreholes in the row on the enemy side in relation to the holes in the row on the friendly side (Figure 3-20). The line closest to the enemy will always contain one less borehole than the friendly line.

c. Make the boreholes on the friendly side 5 feet deep, and load them with 40 pounds of explosive. Make the boreholes on the enemy side 4 feet deep, and load them with 30 pounds of explosive.

d. Use a dual firing system for each line of boreholes. Prime any 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

e. Tamp all holes with suitable material.

There must be a 0.5- to 1.5-second delay in detonation between the two rows of boreholes. Detonate the row on the enemy side frost. Then fire the friendly-side row while the earth from the

enemy-side detonation is still in the air. Use standard delay caps. If the firings cannot be staggered, fire both rows simultaneously. However, the crater produced by a simultaneous detonation will not have the same depth and trapezoidal shape as a relieved-face crater.

3-22. Misfire Prevention. The shock and blast of the first row of charges may affect the delayed detonation of the friendly-side charges. To prevent misfires of the friendly-side charges, protect its detonating-cord lines by covering them with approximately 6 inches of earth.

3-23. Creating Craters in Permafrost and Ice.

a. *Blasting in Permafrost.* Permafrost can be as hard as solid rock. Therefore, you must adapt the procedures for blasting or cratering to accommodate permafrost conditions. In permafrost, blasting requires approximately twice as many boreholes and larger charges than for cratering operations in moderate climates. Blasted, frozen soil breaks into clods 12 to 18 inches thick and 6 to 8 inches in diameter. Because normal charges have insufficient force to blow these clods clear of the boreholes, the span falls back into the crater when the blast subsides.

(1) Boreholes. Before conducting extensive blasting, perform a test on the soil in the area to determine the number of boreholes needed. Dig the boreholes with standard drilling equipment, steam-point drilling equipment, or shaped charges. Standard drilling equipment has one serious defect—the air holes in the drill bits freeze. There is no known method to prevent this freezing. Steam-point drilling is effective for drilling boreholes in sand, silt, or clay, but not in gravel. Place the charges immediately after withdrawing the steam point; otherwise, the area around the borehole thaws and collapses. Shaped charges also are effective for producing boreholes, especially when forming craters. Table 1-3 (page 1-10) lists borehole sizes made by shaped charges in permafrost and ice.

(2) Explosives. If available, use low-velocity explosives, such as ammonium nitrate, for blasting holes in arctic climates. The displacing quality of low-velocity explosives will more effectively clear large boulders from the crater. If only high-velocity explosives are available, tamp the charges with water and let them freeze before detonating. Unless thoroughly tamped, high-velocity explosives tend to blow out of the boreholes.

b. *Blasting in Ice.* Access holes in ice are required for obtaining water and determining the capacity of the ice for bearing aircraft and vehicles. To accommodate rapid forward movements, you must be capable of quickly determining ice capacities. Blasting operations provide this ability.

(1) Boreholes. Make small-diameter access holes using shaped charges. The M2A4 charge will penetrate ice as thick as 7 feet; the M3A1 charge will penetrate over 12 feet of ice (Table 1-3, page 1-10). The M3A1 can penetrate deeper, but it has only been tested on ice approximately 12 feet thick. If placed at the normal standoff distance, the charge forms a large crater at the surface, requiring you to do considerable probing to find the actual borehole. Use a standoff distance of 42 inches or more with the M2A4 shaped charge to avoid excessive crater formation. The M2A4 creates an average borehole diameter of 3 ½ inches. An M3A1 borehole has an average diameter of 6 inches. In late winter, ice grows weaker and changes color from blue to white. Although the structure and strength of ice vary, the crater effect is similar, regardless of the standoff distance.

(2) Craters. Make surface craters with ammonium-nitrate cratering charges or demolition blocks. For the best results, place the charges on the surface of cleared ice and tamp them with

snow. When determining charge size, keep in mind that ice has a tendency to shatter more readily than soil, and this tendency will decrease the charge's size.

c. *Making Vehicle Obstacles.* Create a vehicle obstacle in ice by first making two or more rows of boreholes. Space the boreholes 9 feet apart and stagger them in relation to the holes in the other rows. Suspend Ml12 charges about 2 feet below the bottom surface of the ice with cords tied to sticks, bridging the sticks over the top of the holes. The size of the charge depends on the thickness and condition of the ice. Use test shots to find the optimum amount. This type of obstacle can retard or halt enemy vehicles for approximately 24 hours at temperatures near -24 degrees Fahrenheit.

3-24. Craters as Culverts. Destroying a culvert not more than 15 feet deep may also produce an effective crater. Prime the charges for simultaneous detonation, and thoroughly tamp all charges with sandbags. Destroy culverts that are no deeper than 5 feet by placing explosive charges in the same way as for hasty road craters. Space the boreholes at 5-foot intervals in the fill above and alongside the culvert. In each hole place 10 pounds of explosives per foot of depth

3-25. Craters as Antitank Ditches. Excavate antitank ditches by either the hasty or deliberate cratering method (paragraphs 3-19 and 3-20, pages 3-22 and 3-23).

3-26. Ditching Methods. Explosives can create ditches rapidly. Slope ditches at a rate of 2 to 4 feet of depth per 100 feet of run. Place ditches in areas where natural erosion will aid in producing the correct grade. If you cannot place a ditch in an area aided by erosion, make the ditch deeper, increasing the depth as the length increases. Use the following methods for creating ditches:

a. *Single Line.* The single-line method (Figure 3-21) is the most common ditching method. Detonate a single row of charges along the centerline of the proposed ditch, leaving any further widening for subsequent lines of charges. Table 3-8 gives charge configurations for the single-line method.

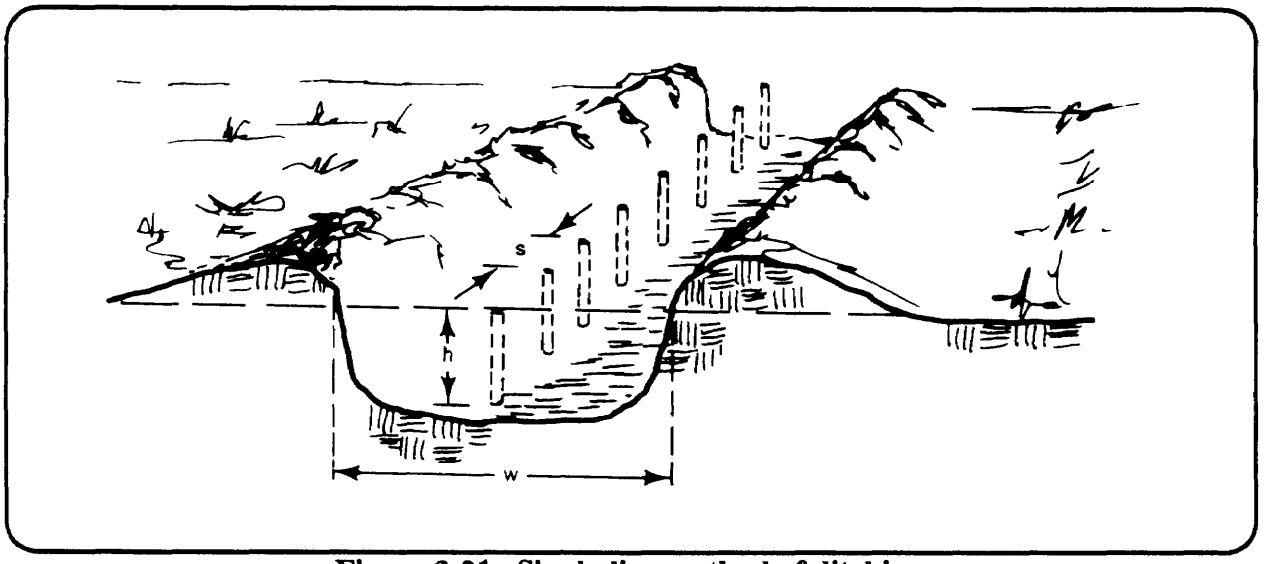


Figure 3-21. Single-line method of ditching

Table 3-8. Single-line ditching explosives data

Serial	Required Ditch Depth (*d*)	Required Width Top of Ditch (*w*) (Feet)	Charges per Hole (Pounds)	Borehole Depth (*h*) (Feet)	Borehole Spacing (*s*) (Feet)
a	b	c	d	e	f
1	2.5	5.0	0.5	1.5	1.5
2	3.0	7.0	1.0	2.0	2.0
3	4.0	9.0	2.0	3.0	3.0
4	6.0	12.0	5.0	5.0	4.0
5	10.0	16.0	10.0	8.0	5.0

b. *Cross Section.* When it is necessary to blast the full width of the ditch in one operation, use the cross-section method (Figure 3-22). Table 3-9 gives charge configurations for the cross-section method. Place an extra charge midway between lines of charges.

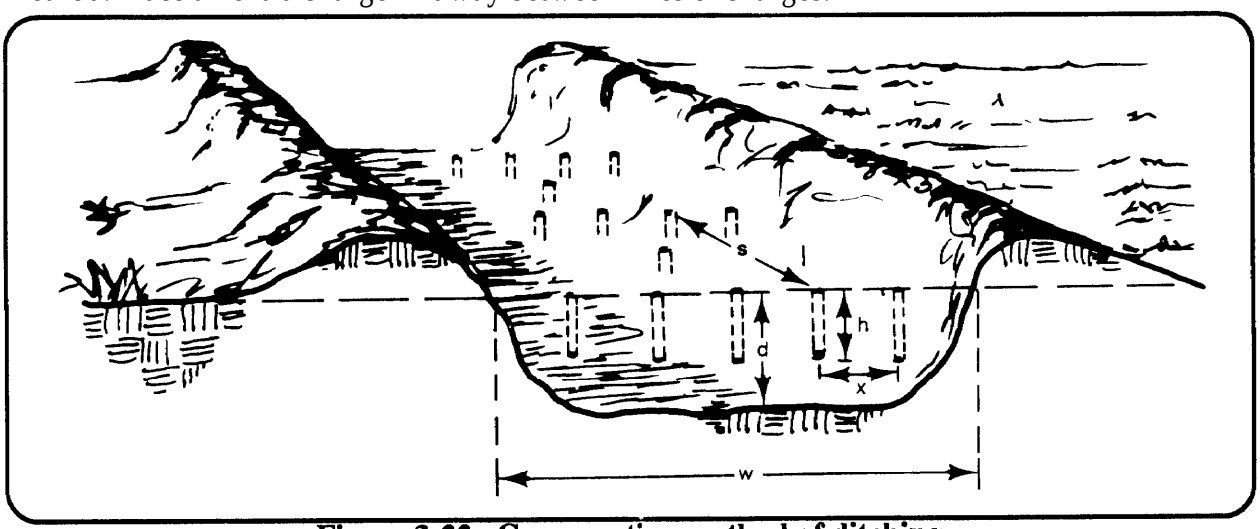


Figure 3-22. Cross-section method of ditching

Table 3-9. Cross-section ditching explosives data

Serial	Required Depth (*d*)	Required Width (*w*) in Feet — Number of Boreholes in Each Cross Section					Charge per Hole (Pounds)	Borehole Depth (*h*) (Feet)	Borehole Spacing (*s*) (Feet)	Row Spacing (x) (Feet)
		3	5	7	9	11				
a	b	c	d	e	f	g	h	l	j	k
1	2.5	7.5	11.0	13.0	16.0	18.0	0.5	1.5	1.3	2.5
2	3.0	10.0	13.0	16.0	19.0	22.0	1.0	2.0	1.5	3.0
3	4.0	14.0	19.0	24.0	29.0	34.0	2.0	3.0	2.5	4.5
4	6.0	20.0	28.0	36.0	44.0	52.0	5.0	5.0	4.0	6.0
5	10.0	26.0	33.0	46.0	56.0	65.0	10.0	7.0	5.0	8.0

Section VI. Land-Clearing Charges

3-27. Stump Removal. Stumps have two general root types: taproot and lateral root (Figure 3-23). Measure the stump diameter 12 to 18 inches above ground level. Round the diameter to the next higher ½ foot. Use 1 pound of explosive per foot of diameter for dead stumps and 2 pounds of explosive per foot of diameter for live stumps. If removing the complete tree, increase the amount of explosive by 50 percent. If you cannot identify the root type, assume the tree has a lateral root structure and proceed accordingly.

a. *Taprooted Stumps.* Two methods are common for removing taprooted stumps. One method is to drill a hole in the taproot and place the charge in the hole. Another method is to place charges on both sides of the taproot, creating a shearing effect (Figure 3-23). If possible, place the charges in contact with the root and at a depth approximately equal to the diameter of the stump.

b. *Laterally Rooted Stumps.* When blasting laterally rooted stumps, drill sloping holes between the roots (Figure 3-23). Drill the holes and place the charges as closely to the center of the stump as possible, at a depth equal to the radius of the stump base. Trees with large lateral roots may require additional charges. Place the additional charges directly underneath the lame lateral roots.

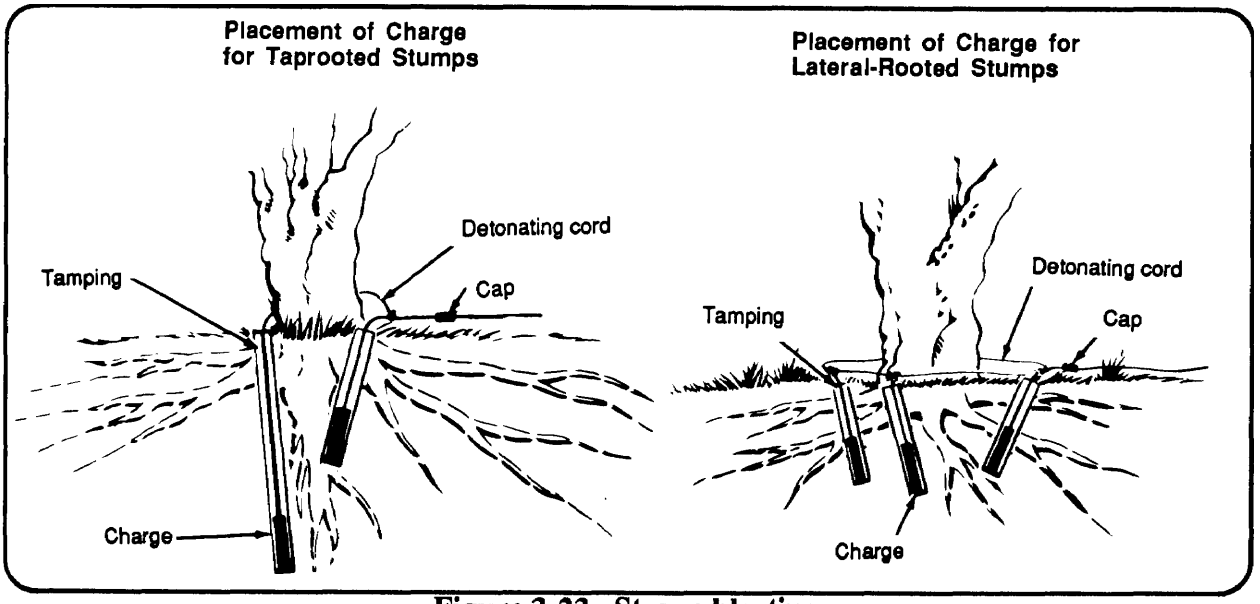


Figure 3-23. Stump blasting

3-28. Boulder Removal. Blasting is an effective way to remove boulders. The most practical methods are snake-hole, mud-cap, and block-hole:

a. *Snake-Hole Method.* This method involves digging a hole beneath the boulder large enough to hold the charge. Pack the charge under and against the boulder as shown in Figure 3-24. Table 3-10 lists the required charge sizes.

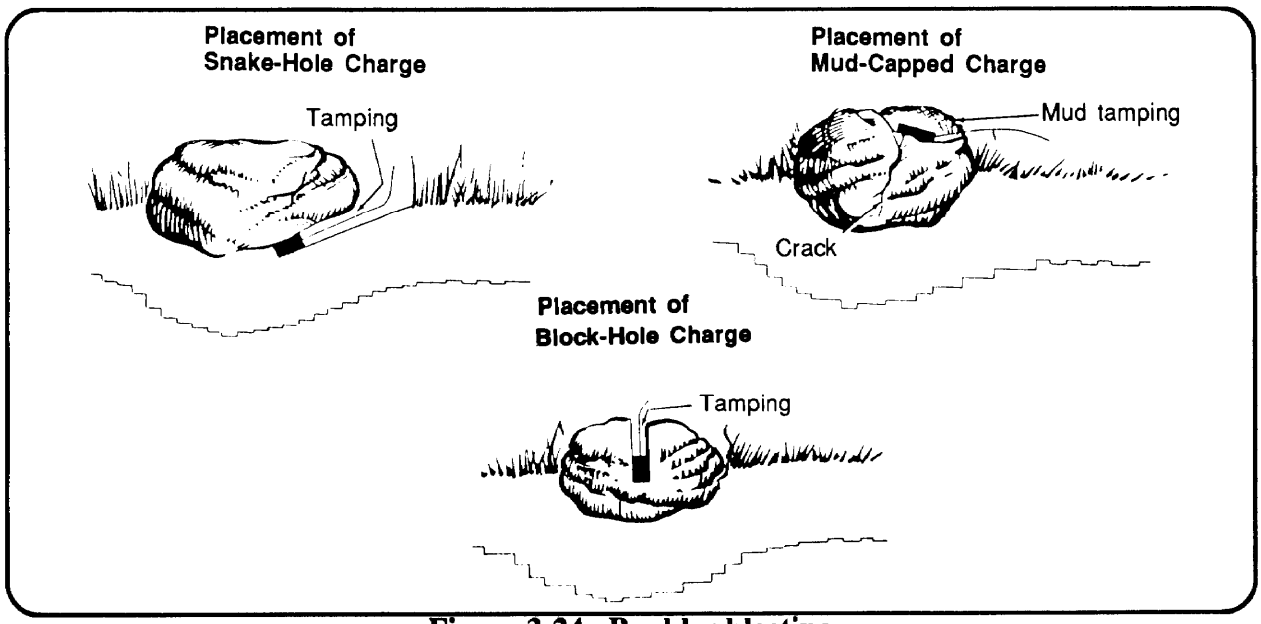


Figure 3-24. Boulder blasting

Table 3-10. Boulder-blasting charges

Boulder Diameter (Feet)	Charge Size (Pounds)		
	Block-Hole Method	Snake-Hole Method	Mud-Cap Method
3	0.250	0.75	2.0
4	0.375	2.00	3.5
5	0.500	3.00	6.0

b. *Mud-Cap Method.* Place the charge in a crack or seam in the boulder (Figure 3-24, page 3-28). Cover the charge with 10 to 12 inches of mud or clay. Table 3-11 lists the required charge sizes.

c. *Block-Hole Method.* Drill a hole in the top of the boulder deep and wide enough to hold the amount of explosive required (Table 3-11). Prime the charge with detonating cord and tamp firmly (Figure 3-24, page 3-28).

3-29. Springing Charge. A springing charge is a comparatively small charge for enlarging a borehole to accommodate a larger charge. At times, you may have to detonate two or more springing charges in succession to make the chamber large enough for the final charge. Wait at least two hours between firing successive charges to allow the borehole to cool, unless you cool the hole with water or compressed air. For soils, use several strands of detonating cord, 5 to 6 feet long, taped together to forma multicord wick. For best results, extend the wick the full length of the borehole. As a general rule, one strand of detonating cord (single-cord wick) will widen a borehole's diameter by about 1 inch. For example, a 10-cord wick will create a 10-inch diameter borehole. Make the initial borehole by driving a steel rod approximately 2 inches in diameter into the ground to the required depth. Place the wick into the initial borehole with an inserting rod or some other field-expedient device. The detonating-cord wick works best in hard soils (paragraph D-7, page

D-4). If placing successive charges in the same borehole, use water, or compressed air, or wait two hours to cool the borehole before placing the next charge.

3-30. Quarrying. Military quarries are generally open-faced and mined by the single- or multiple-bench method. TM 5-332 gives detailed information on military quarries.

Section VII. Special Applications

3-31. Survivability Positions. In many circumstances, the use of explosives can reduce digging time and effort. Use explosives only in soil that would normally be excavated by pick and shovel. Explosives are not recommended for excavations less than 2 feet deep. Use small charges buried and spaced just enough to loosen the soil, limiting the dispersion of soil to as small an area as possible. Do not attempt to form a crater doing this spreads soil over a large area, affecting concealment and weakening the sides of the finished position. Explosives can create individual fighting positions and larger crew-served, gun, or vehicle positions. Using explosives in this manner requires some advance preparation. In the case of an individual fighting position, the preparation time may exceed time required to prepare the position by traditional methods.

a. *Depth.* Place charges 1 foot shallower than the required depth, to a maximum of 4 feet. If the required depth is greater than 5 feet, dig the position in two stages, dividing the required depth in half for each stage. Make the boreholes with an earth auger, wrecking bar, picket driver, or other expedient device.

b. *Spacing.* For rectangular excavations, dig the boreholes in staggered lines. For circular excavations, dig the boreholes in staggered, concentric rings. The spacing between boreholes in each line or ring and between lines or rings should be between 1 and 1.5 times the borehole depth. Ensure all charges are at least 2 feet inside the proposed perimeter of the excavation. Also, dig an 8-by 8-inch channel around the outer perimeter of the proposed excavation, with the outer edge of the channel forming the outer edge of the finished excavation. Figure 3-25 shows layouts for rectangular and circular excavations.

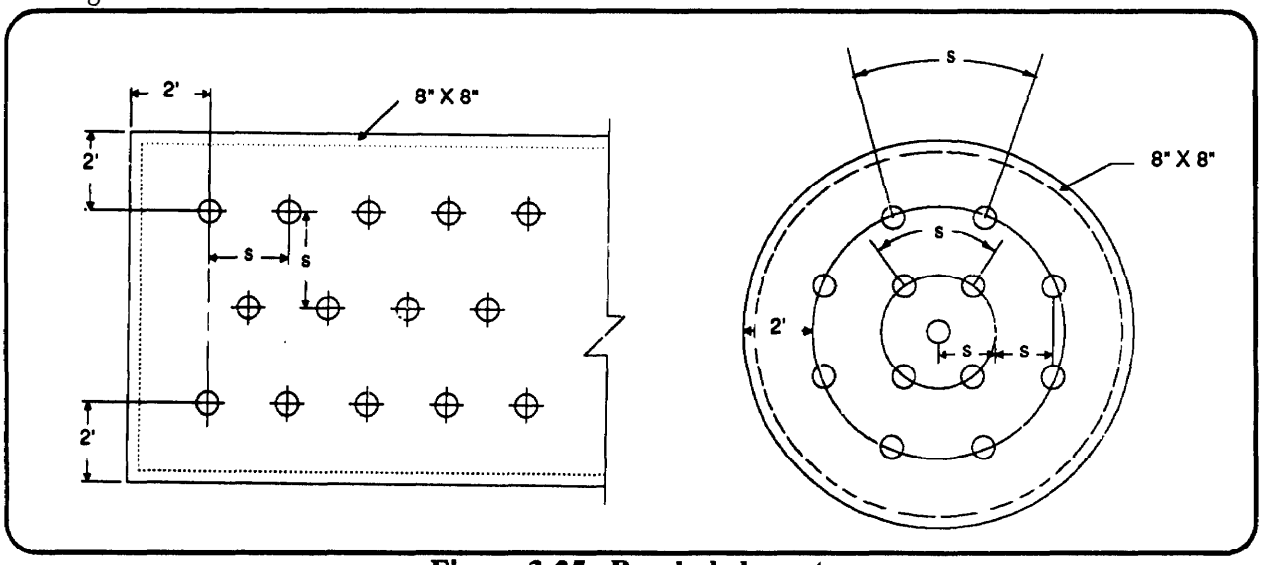


Figure 3-25. Borehole layouts

c. *Charge Size.* Use ¼-pound charges of plastic explosive to dig foxholes. For large excavations, use charges between ½ and 1 ½ pounds, depending on spacing and soil characteristics. A test shot is usually necessary to determine the correct charge size.

d. *Concealment.* Reduce explosion noise and spoil scatter by leaving any sod in place and covering the site with a blasting mat. Improvise blasting mats by tying tires together with natural or synthetic rope (steel-wire rope is unacceptable) or by using a heavy tarpaulin.

3-32. Equipment Destruction.

WARNING
Steel-cutting charges produce metal fragments.
Proper precautions should be taken to protect personnel.
Refer to Table 6-3, page 6-7.

a. *Guns.* Destroy gun barrels with explosives or their own ammunition. Also be sure to remove or destroy the small components, such as sights and other mechanisms.

(1) Explosive Method.

(a) To prepare a gun for demolition, first block the barrel just above the breach. For small-caliber guns that use combined projectile-propellant munitions, solidly tamp the first meter of the bore with earth. For heavier guns that use projectiles separate from propellants, simply load a projectile and aim the tube to minimize damage should the round be ejected.

(b) Charge Size. Table 3-11 (page 3-32) details the charge size required for standard barrel sizes. If necessary, determine the required charge size using the following formula:

$$P = \frac{D^2}{636} \qquad \textbf{(3-l0)}$$

where–

P = *quantity of explosive (any high explosive), in pounds.*
D = *bore size of the barrel, in millimeters.*

(c) Placement. Pack the explosive, preferably C4, into the breach, immediately behind the tamping. Place the plastic explosive in close contact with the chamber. Close the breach block as far as possible, leaving only enough space for the detonating cord to pass without being bent or broken. If time permits, place 15-pound charges on the drive wheels of tracked guns and on the wheels and axles of towed guns. Connect the branch lines in a junction box or use a ring main. Simultaneously detonate all charges.

Table 3-11. Gun-destruction charge sizes

Serial	Barrel Size (Millimeters)	Charge Size (Pounds)
a	b	c
1	76	10
2	105	18
3	120	23
4	155	38
5	203	66
Note: Determine appropriate charge sizes for barrel sizes not listed by comparing them to known barrel sizes. For example, you would use the explosive weight in Serial 3 for a 112-mm barrel (23 pounds); Serial 4 for a 152-mm barrel (38 pounds).		

(2) Improvised Method. When block explosives are not available, destroy a gun with its own ammunition. Insert and seat one round in the muzzle end and a second charge, complete with propellant charge (if required), in the breach end of the tube. Fire the gun from a safe distance, using the gun's own mechanism. Use a long lanyard and ensure the firing party is under cover before firing the gun.

b. *Vehicles.* To destroy friendly vehicles, refer to the applicable TM. Use the following priorities when destroying vehicle components:

- Priority 1. Carburetor, distributor, fuel pump or injectors, and fuel tanks and lines.
- Priority 2. Engine block and cooling system.
- Priority 3. Tires, tracks, and suspension system.
- Priority 4. Mechanical or hydraulic systems (where applicable).
- Priority 5. Differentials and transfer case.
- Priority 6. Frame.

(1) Armored Fighting Vehicles (AFVs). Destroy AFVs beyond repair by detonating a 25-pound charge inside the hull. The charge may be a bulk 25-pound charge or a number of smaller charges, placed on the driving, turret, and gun controls. To increase the amount of damage to the AFV, ensure the ammunition within the AFV detonates simultaneously with the other charges, and ensure all hatches, weapons slits, and other openings are sealed. If it is not possible to enter the AFV, place the charges under the gun mantle, against the turret ring, and on the final drive (Figure 3-26). If explosives are not available, destroy the AFV by using antitank weapons or fire, or destroy the main gun with its own ammunition.

(2) Wheeled Vehicles.

(a) Explosives method. Destroy wheeled vehicles beyond repair by wrecking the vital parts with a sledgehammer or explosives. If high explosives are available, use 2-pound charges to destroy the cylinder head, axles, and frame.

(b) Improvised method. Drain the engine oil and coolant and run the engine at full throttle until it siezes. Finish the destruction by burning the vehicle (ignite the fuel in the tank).

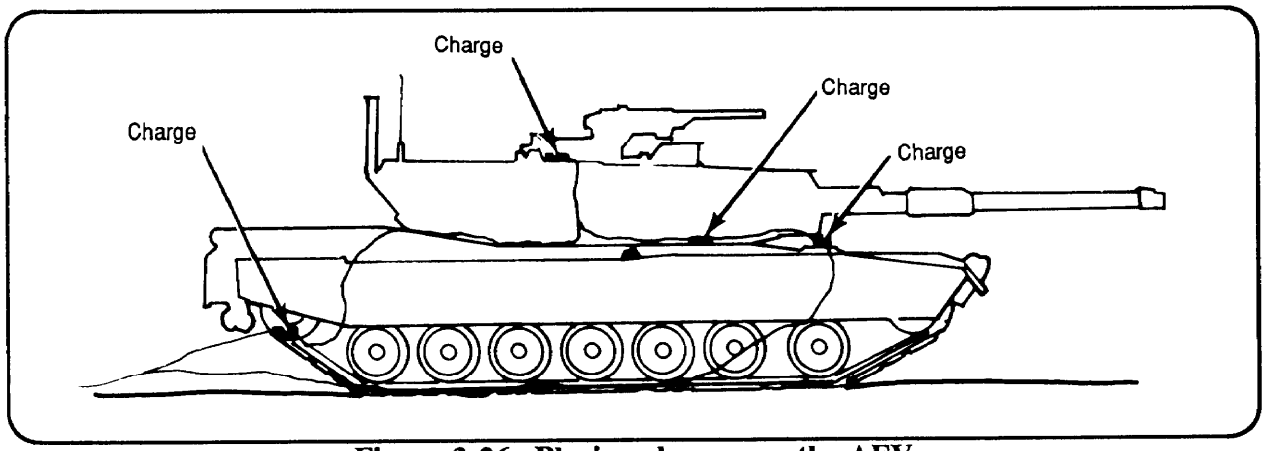


Figure 3-26. Placing charges on the AFV

Chapter 4
Bridge Demolition

Section I. Requirement

4-1. Purpose of Bridge Demolition. The purpose of bridge demolitions is to create gaps in bridges by attacking key components of the bridge. This makes gaps large enough to make repair uneconomical and to force the enemy to construct other bridges on other sites. The minimum gap required must exceed the enemy's assault bridging capability by 5 meters. For planning purposes, use 25 meters as the minimum gap size, but 35 meters is better. The gap may be less than 25 meters if enemy forces must depend on the demolished bridge components to bear their assault bridging and there is insufficient bearing capacity in the remains to carry the loads.

4-2. Degree of Destruction. The complete demolition of a bridge usually involves the destruction of all the components (spans, piers, and abutments). Complete demolition may be justified when the terrain forces the enemy to reconstruct a bridge on the same site. However, complete destruction is not normally required to meet the tactical objective. Select the method of attack that achieves the tactical goal, with a minimum expenditure of resources.

4-3. Debris. Debris may cause enemy forces serious delays if it obstructs the gap (Figure 4-l). Debris also provides excellent concealment for mines and booby traps. Whenever possible, demolish bridges in such a way that the resulting debris hinders reconstruction.

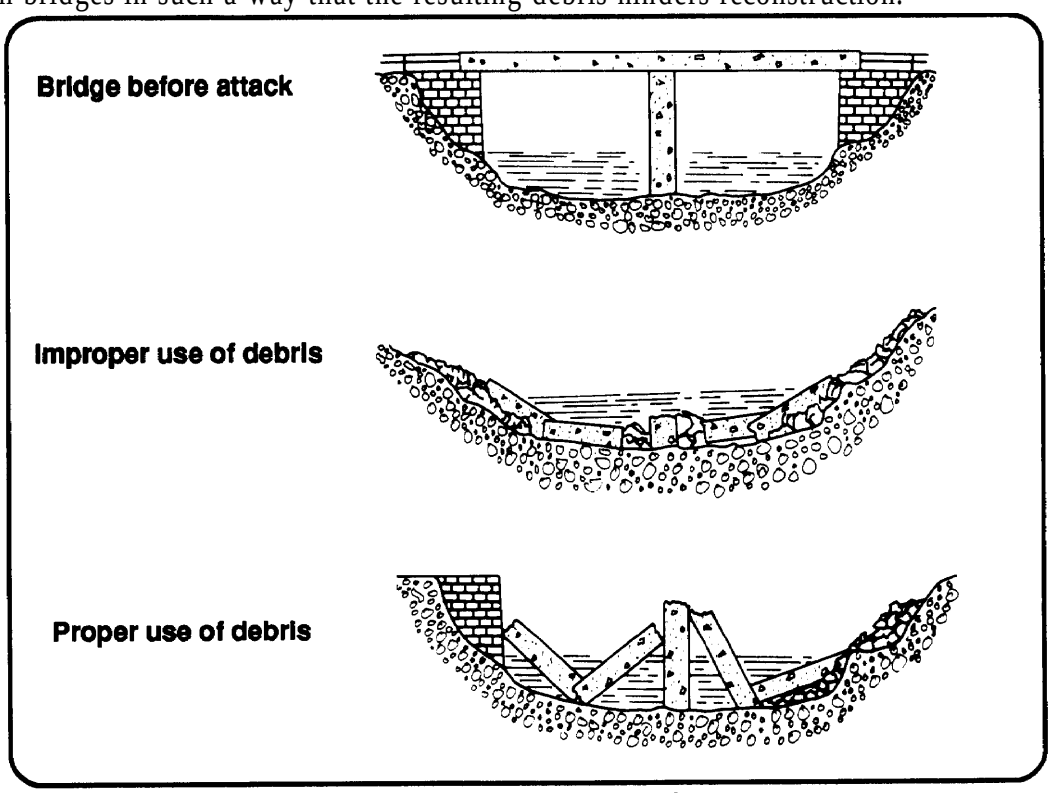


Figure 4-1. Use of debris

Section II. Considerations

4-4. Bridge Categories. The first step in any efficient bridge demolition is to categorize the bridge correctly. The term *categorization* has been adopted to avoid confusion with *classification*, which is concerned with the load-carrying capacity of bridges. The correct categorization of bridges, coupled with an elementary knowledge of bridge design, allows you to select a suitable attack method. All bridges fit into one of three categories:

a. *Simply Supported.* In simply supported bridges, the ends of each span rest on the supports; there are no intermediate supports. The free-bearing conditions shown in Figure 4-2 represent any bearing that allows some horizontal movement (for example, roller bearings, sliding bearings, and rubber bearing pads).

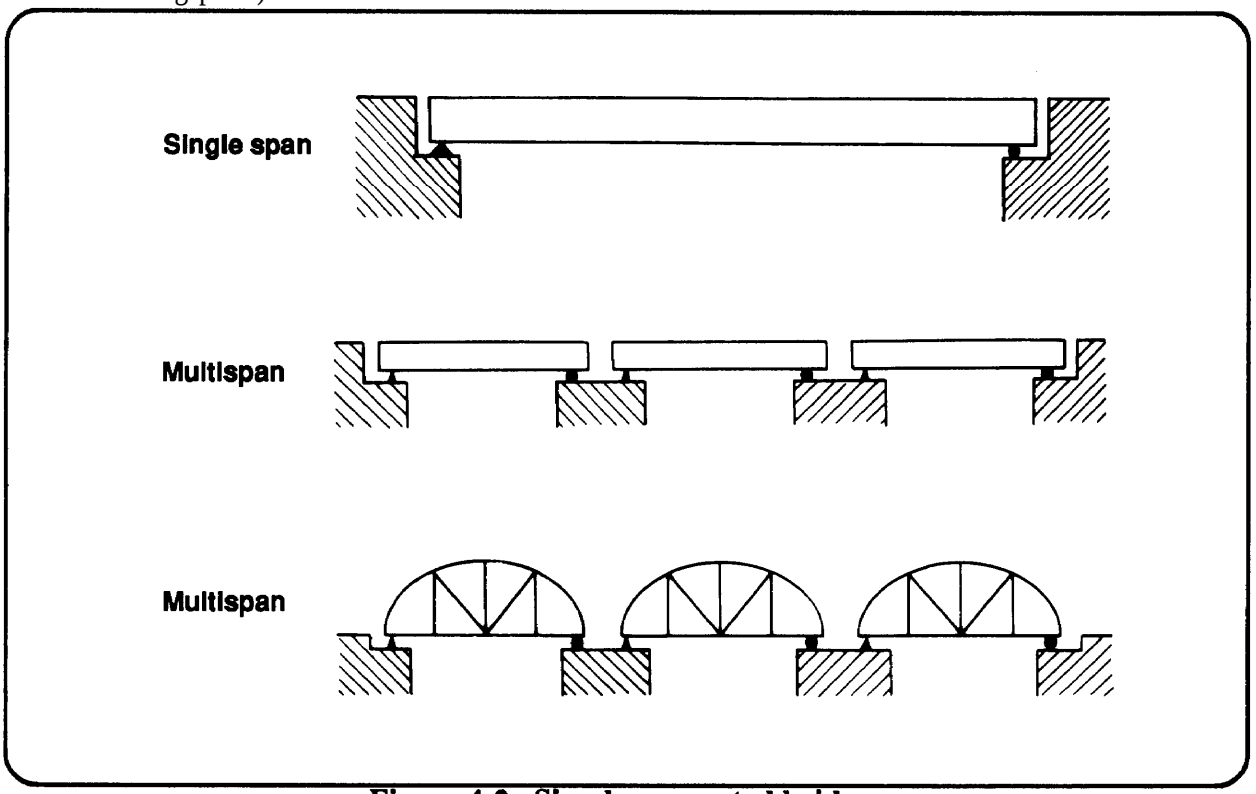


Figure 4-2. Simply supported bridges

b. *Miscellaneous.* Miscellaneous bridges form a small proportion of bridge structures. The theoretical principles governing these bridges determine the appropriate methods of attack. Examples of bridges in this category are suspension, lift, and cable-stayed bridges.

c. *Continuous.* If a bridge does not fit the miscellaneous category and is not simply supported, categorize it as a *continuous* bridge. Hence, *continuous* has a wider meaning than *multispan, continuous-beam bridges,* as is normally implied.

4-5. Stages of Destruction. When designing a bridge demolition, the first priority is to create a gap. Accomplishing this may require one or two attacks. Further actions that improve the obstacle may follow, if the situation permits.

a. *Minimum Conditions.* There are two minimum conditions for successful bridge demolition:

- You must design a proper collapse mechanism.
- You must ensure the attacked span will be free to move far enough, under its own weight, to create the desired obstacle.

(1) Condition 1. Under normal conditions, a bridge is a stable structure. In bridge demolitions, the goal is to destroy the appropriate parts of a bridge so that it becomes unstable and collapses under its own weight. In other words, you form a collapse mechanism. This may involve either cutting completely through all structural members or creating points of weakness in certain parts of the bridge. Figure 4-3 shows an improper collapse mechanism and the hinges that have not been formed. At times, making bridges unstable by attacking their piers rather than their superstructures is easier, but it is still possible for bridges not to collapse, even though they lost the support provided by one or more of their piers. To avoid this type of demolition failure, place the charges on the structural members of the superstructure, immediately above the piers being attacked.

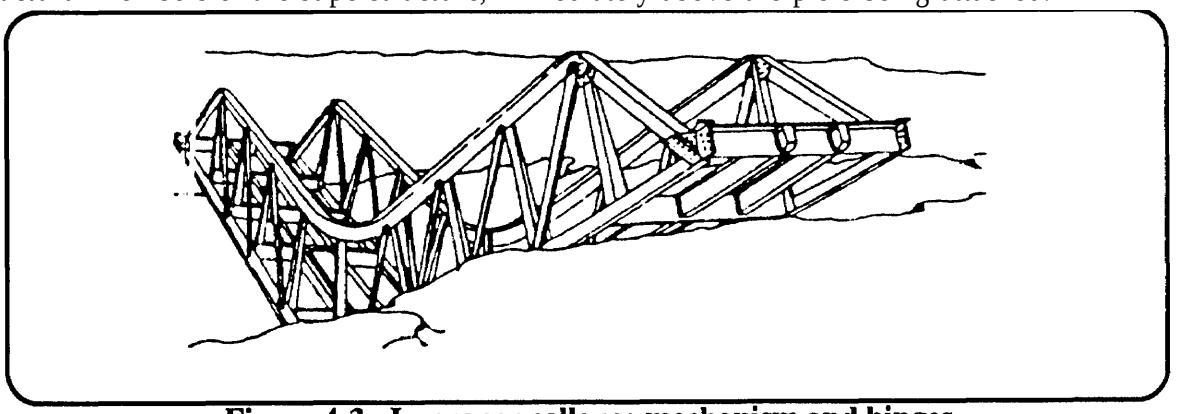


Figure 4-3. Improper collapse mechanism and hinges

(2) Condition 2. Figure *4-4* shows a bridge demolition where the collapse mechanism has formed, but where, because the bridge span has jammed before moving far enough, it has failed to form the desired obstacle. To complete the demolition in this example, you need to remove only a small portion of the abutment to allow the span to swing down freely.

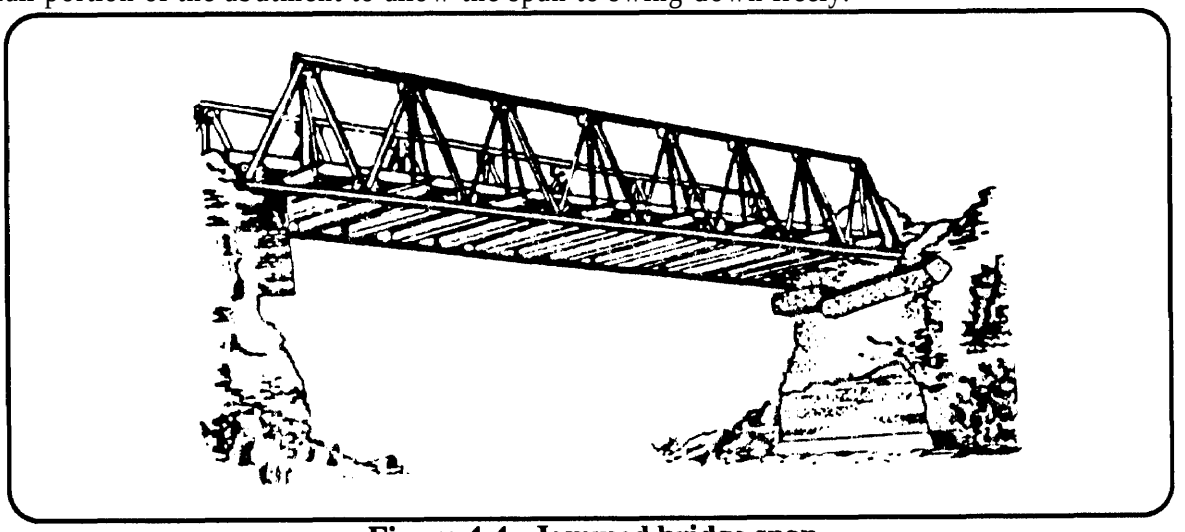


Figure 4-4. Jammed bridge span

b. *Types of Collapse Mechanism.* Figures 4-5 through 4-7 illustrate the three basic collapse mechanisms.

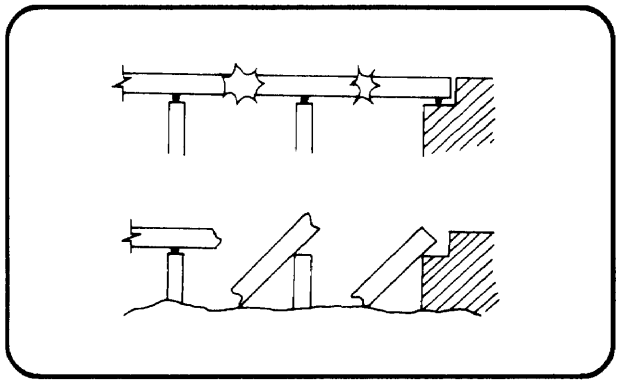


Figure 4-5. See-saw collapse mechanism

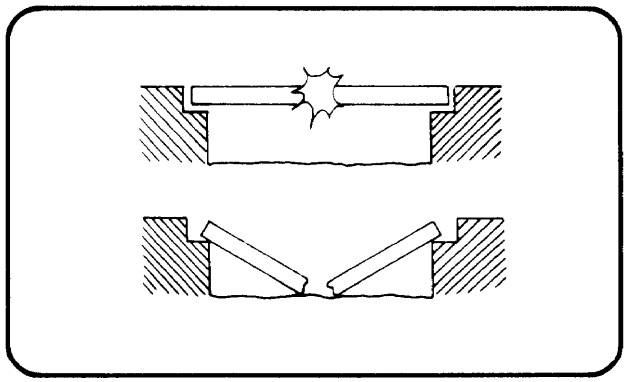


Figure 4-6. Beam collapse mechanism

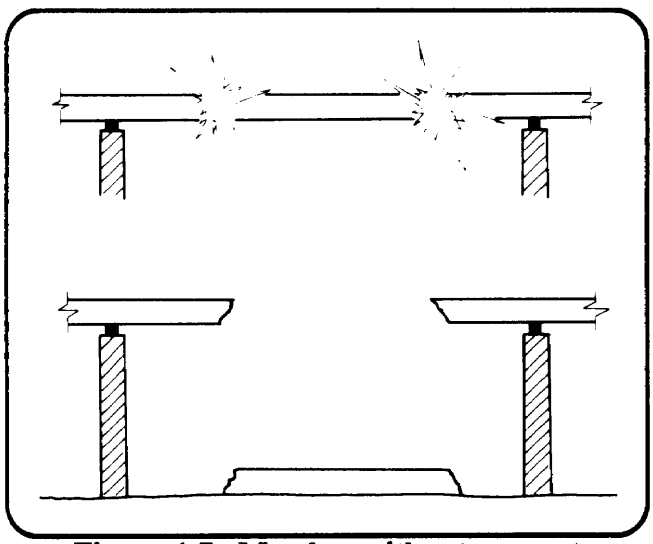


Figure 4-7. Member without support collapse mechanism

c. Unsuccessful Bridge Demolitions. Two possible reasons for unsuccessful bridge demolitions are—

(1) No-Collapse Mechanism. The formation of cantilevers (Figure 4-8) is a typical example of a no-collapse mechanism being formed. The likelihood of this occurring is high when attacking continuous bridges.

(2) Jamming. The span, once moved by the collapse mechanism, jams before moving far enough to create the desired obstacle. The most likely causes of jamming are the formation of a three-pin arch or a cranked beam (Figure 4-9). When attacking bridge spans, always consider the possibility of jamming during bottom and top attacks.

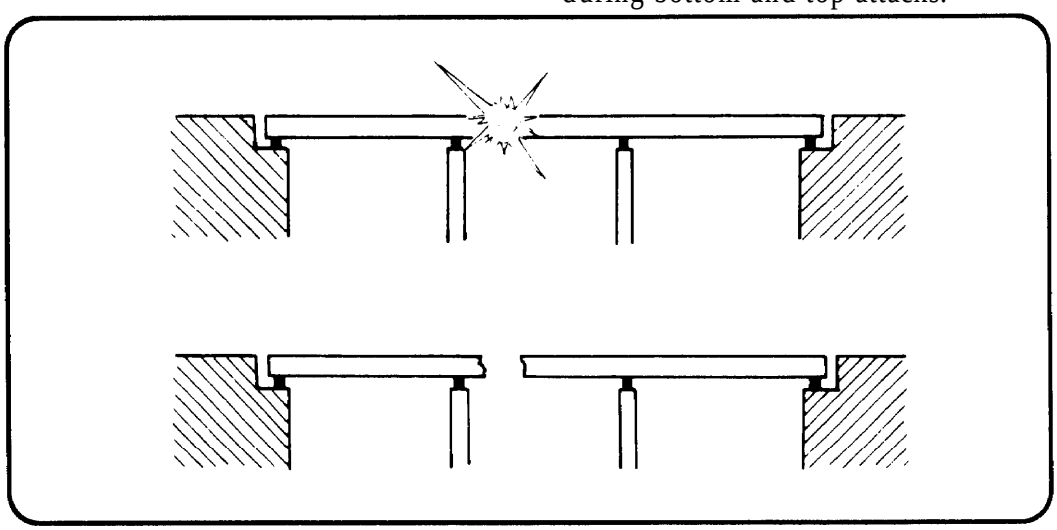


Figure 4-8. Cantilever effect

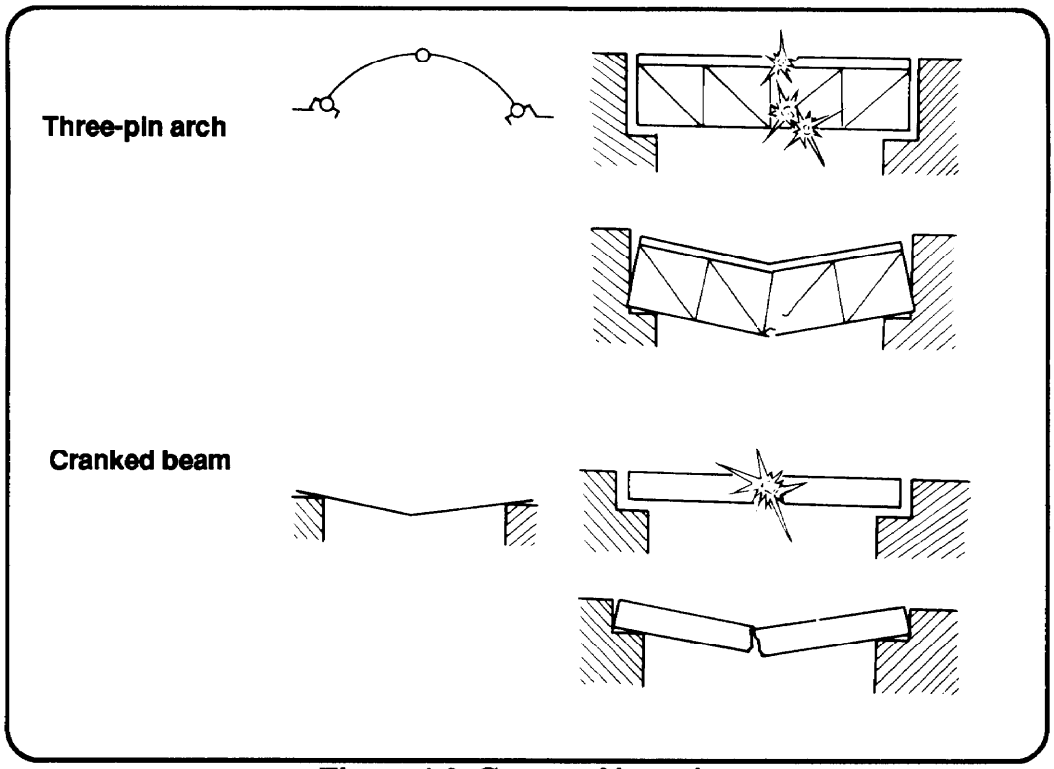


Figure 4-9. Causes of jamming

4-6. Bottom Attack. In the bottom attack, the hinge forms at the top. As the span falls, the cut ends at the bottom move outward. The span may form a three-pin arch and fail to fall completely if the distance the cut ends must move is greater than the total end clearance between the span ends and the pier or abutment faces (Figure 4-10). If a three-pin arch situation is likely, do not attempt a bottom attack.

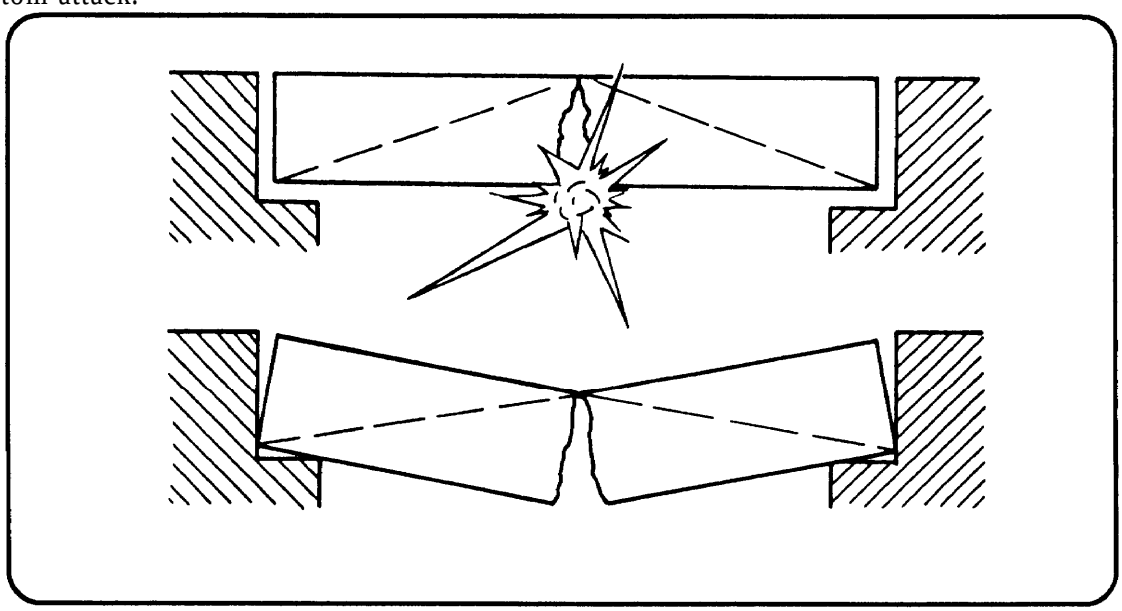


Figure 4-10. Three-pin arch effect

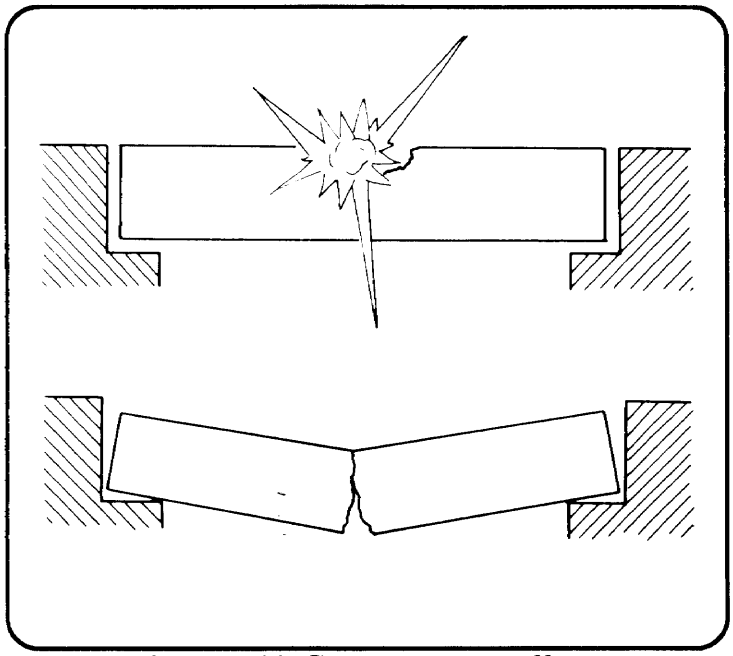


Figure 4-11. Cranked-beam effect

4-7. Top Attack. In a top attack, the hinge forms at the bottom. As the span falls, the cut ends at the top move inward. Some bridges may jam along the faces of the cut before the ends of the span have fallen off the abutments, forming a cranked beam (Figure 4-11). Ensure the length of span removed (L_C) at the top is sufficient to prevent the formation of a cranked beam.

4-8. Efficient Demolition Methods. To ensure that a demolition achieves collapse with reasonable economy, consider the factors required to achieve an efficient demolition. The best balance between these factors will depend on the particular demolition under consideration. An efficient demolition should—

a. Achieve the desired effect.

b. Use the minimum amount of resources (time, manpower, and explosives).

c. Observe the proper priorities. The demolition reconnaissance report must clearly state the priorities and separately list the requirements for Priority 1 actions and Priority 2 improvements (priorities are explained below). If a sufficient gap will result by attacking bridge spans, do not perform the Priority 2 improvements unless the report specifies complete destruction or an excessively long gap. If the total gap spanned by a bridge is too small to defeat enemy assault bridging, consider the site an unsuitable obstacle unless the gap can be increased. Your engineer effort may be better applied elsewhere. Alternatively, to improve an obstacle, it may be necessary to increase the gap by demolishing the abutments and building craters on the immediate approaches. In this case, you should also attack nearby bypass sites (place mines and craters).

(1) Priority One. Create the desired obstacle. The minimum gap required is 5 meters greater than the enemy's assault bridging capability. Ideally, accomplish the demolition with the first attempt. However, many reinforced- or prestressed-concrete bridges may require two-stage attacks. Attacking the friendly side of spans will permit economical reconstruction of the bridge at a later date, if necessary.

(2) Priority Two. Make improvements to the gap. Perform this activity only when it is specified on the demolition reconnaissance report. When no reconnaissance report has been issued and time permits, perform improvements in the sequence specified below. Deviate from this sequence only under exceptional circumstances or when directed to do so by the responsible commander. The standard sequence of demolition is to-

(a) Destroy and mine the blown abutment.

(b) Lay mines in likely bypasses.

(c) Blast craters and lay mines in likely approaches.

(d) Destroy the piers.

4-9. Concrete-Stripping Charges.

a. *Description.* Concrete-stripping charges are bulk, surface-placed charges designed for removing concrete from reinforced-concrete beams and slabs and exposing the steel reinforcement. Although these charges cause some damage to the reinforcing steel, you will not be able to predict the extent of this damage. These charges are effective against reinforced-concrete beams and slabs up to 2 meters thick. Figure 4-12 shows the effect of the concrete-stripping charge. Using the proper charge size for the thickness of the target will—

- Remove all concrete from above the main reinforcing steel.
- Remove all concrete from below the main reinforcing steel (spalling).
- Damage the main reinforcing steel to some extent.
- Destroy the minor reinforcing steel near the surface under the charge.

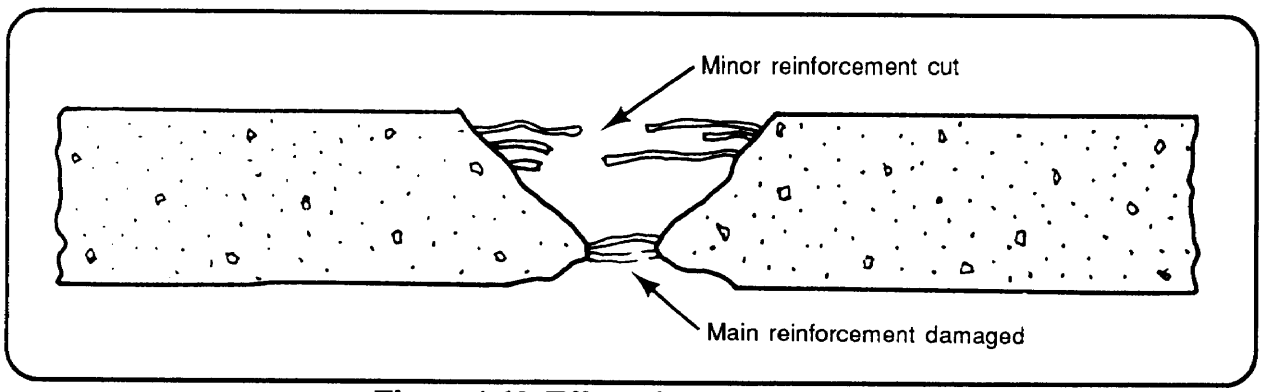


Figure 4-12. Effect of concrete charge

b. *Charge Calculations (Simply Supported Bridges).* For all simply supported concrete bridges, removing all concrete over a specified L_C will cause collapse. For beam-and-slab bridge spans (T-beam and I-beam bridges), determine the charge sizes for the beams and slab separately. Example A-12 (page A-10) shows how to calculate beam-and-slab bridge charges. Use the following procedure for determining charge sizes for simply supported spans:

(1) Calculate the mass of the charge required:

$$P = 3.3(3.3\,h + 0.5)^3 \qquad (4\text{-}1)$$

where—

P = *required charge size, in pounds per meter of bridge width.*
h = *beam or slab plus roadway depth, in meters (minimum is 0.3 meters and maximum is 2 meters).*

(2) Calculate the width of the required ditch. The charge will produce a ditch across the width of the bridge. To determine the width of this ditch, use the following formula:

$$W_d = 2h + 0.3 \qquad (4\text{-}2)$$

where-

W_d = *ditch width, in meters.*
h = *overall roadway and beam or slab depth, in meters.*

(3) Compare the required W_d with the required L_c, and take the appropriate action:

- If L_c is equal to or less than W_d, use one row of charges as specified by *P*.
- If L_c is greater than W_d, but less than twice W_d, increase the size of charge by 10 percent.
- If L_c is twice W_d, double the charge and place them in two lines, side by side.

(4) Place charges in a continuous line across the full width of the bridge at the point of attack. The shape of the end cross section of the charge should be such that the width is between one and three times the height.

(5) Tamp the charges, if required. No tamping is required for the concrete stripping charge as calculated, but if tamping with two filled sandbags per pound of explosive is used, reduce the calculated mass of charge by one third. The width of ditch formed will remain the same as for the original mass of charge.

Section III. Bridge Attacks

4-10. Guidelines (Continuous and Simply Supported Bridges). There are a number of factors that will assist you inadequately differentiating simply supported bridges from continuous bridges. Figure 4-13 and the subparagraphs below describe these factors.

a. *Continuity.* In simply supported bridges, the entire superstructure is composed of a span or multiple spans supported at each end. The main structural members (individual spans) meet end to end, and each intermediate pair of ends is supported by a pier. The single ends are supported by the abutments. In continuous bridges, the main structural members are formed into one piece and do not have breaks over the piers, if any are present.

b. *Construction Depth.* In multispan, simply supported bridges, the construction depth of the span may decrease at the piers. In continuous bridges, construction depth frequently increases at the piers.

c. *Flange Thickness (Steel-Girder Bridges).* In simply supported, steel-girder bridges, the thickness of the flange frequently increases at midspan. In continuous bridges, the size of the flange frequently increases over the piers.

d. *Bearing.* Multispan, simply supported bridges require two lines of bearing at the piers; continuous bridges require only one.

e. *Category Selection.* The external appearance of a bridge can sometimes be deceptive. Whenever possible, consult construction drawings to ascertain the correct bridge category. If

drawings are not available and there is any uncertainty about the category to which the bridge belongs, assume the bridge is of continuous construction. Since more explosive is necessary to demolish a continuous bridge, assuming a continuous construction will provide more than enough explosive to demolish a bridge of unknown construction.

f. *Reconnaissance Procedures.* To correctly use the tables in Appendix H, decide whether the bridge is in the simply supported, continuous, or miscellaneous category, and follow the procedures outlined in the appropriate paragraph.

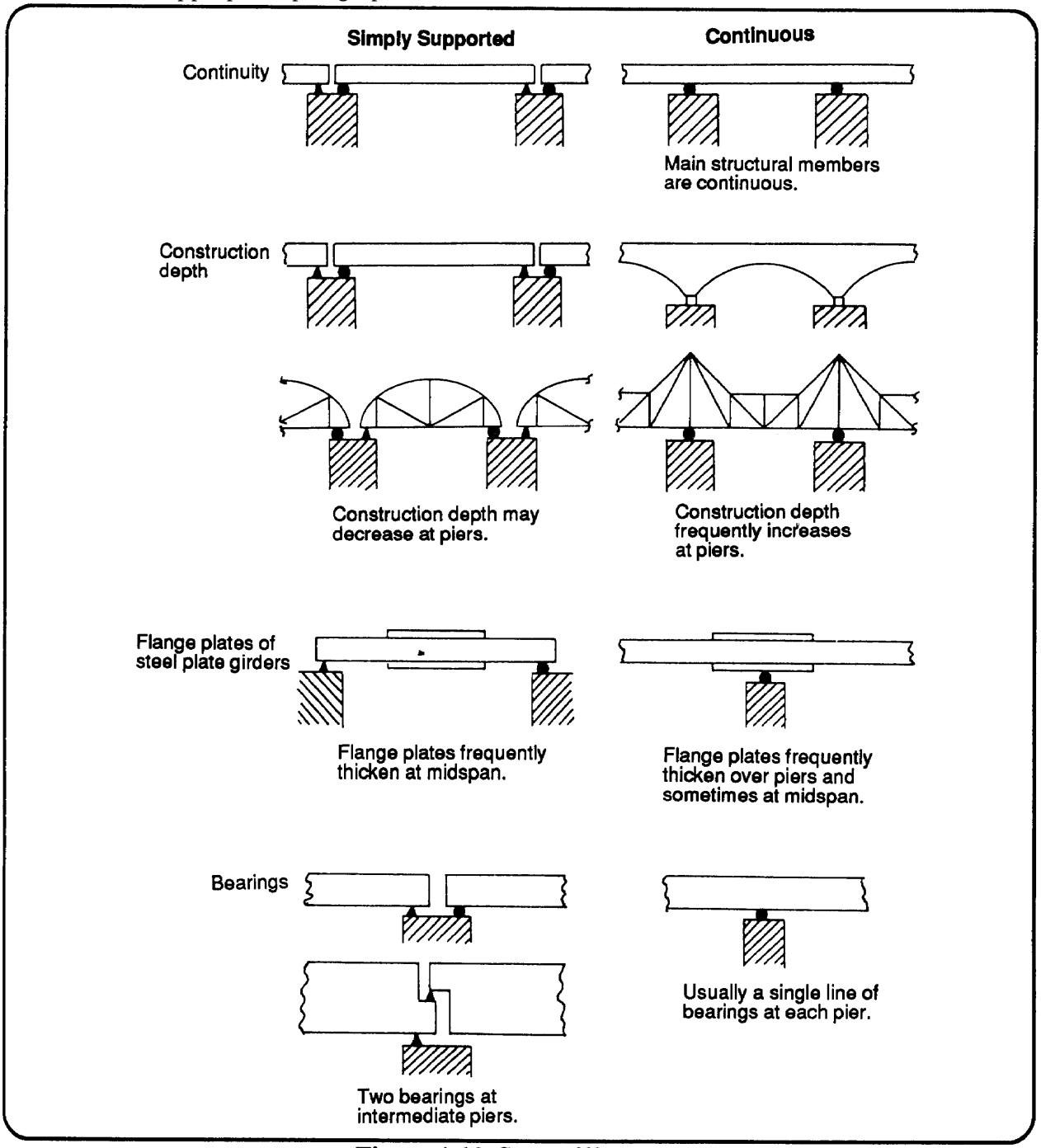

Simply Supported
Continuous
Continuity
Main structural members are continuous.
Construction depth
Construction depth may decrease at piers.
Construction depth frequently increases at piers.
Flange plates of steel plate girders
Flange plates frequently thicken at midspan.
Flange plates frequently thicken over piers and sometimes at midspan.
Bearings
Usually a single line of bearings at each pier.
Two bearings at intermediate piers.

Figure 4-13. Span differences

4-11. Simply Supported Bridges.

a. *Categorization.* Figure 4-14 is a categorization chart for simply supported bridges. Enter this chart from the left, and follow the lines and arrows across to the right. The path you select must include all categorization terms applicable to the simply supported bridge you plan to demolish. There are four main subcategories: steel beam, steel truss, concrete beam and slab, and bowstring. The first three are further subdivided into deck bridges, which carry their loads on top of the main structural members. When dealing with deck bridges, note the locations of bearing (supporting the top or bottom chord or flange), as this will influence the possibility of jamming.

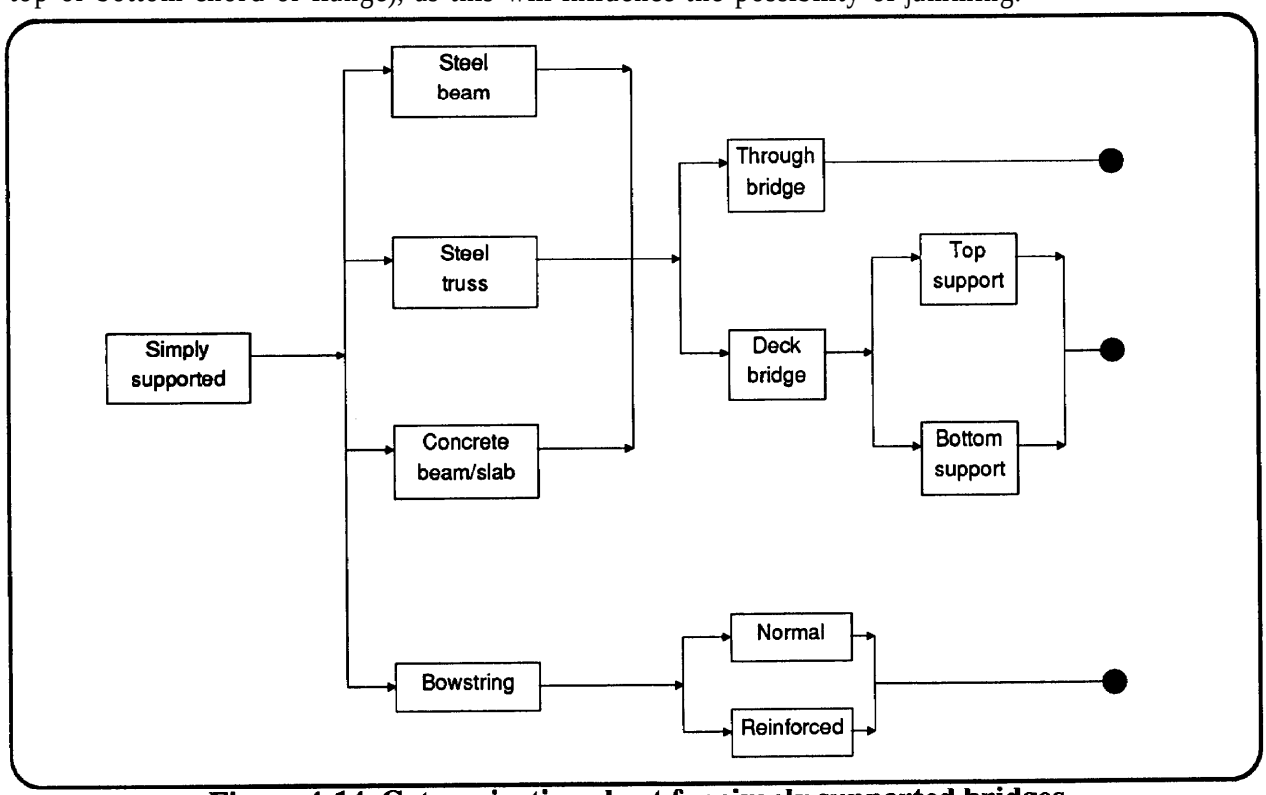


Figure 4-14. Categorization chart for simply supported bridges

(1) Steel-Beam Bridges. Stell-beam bridges may be constructed of normal steel-beam, plate-girder, or box-girder spans. Figure 4-15 shows typical cross sections of these spans.

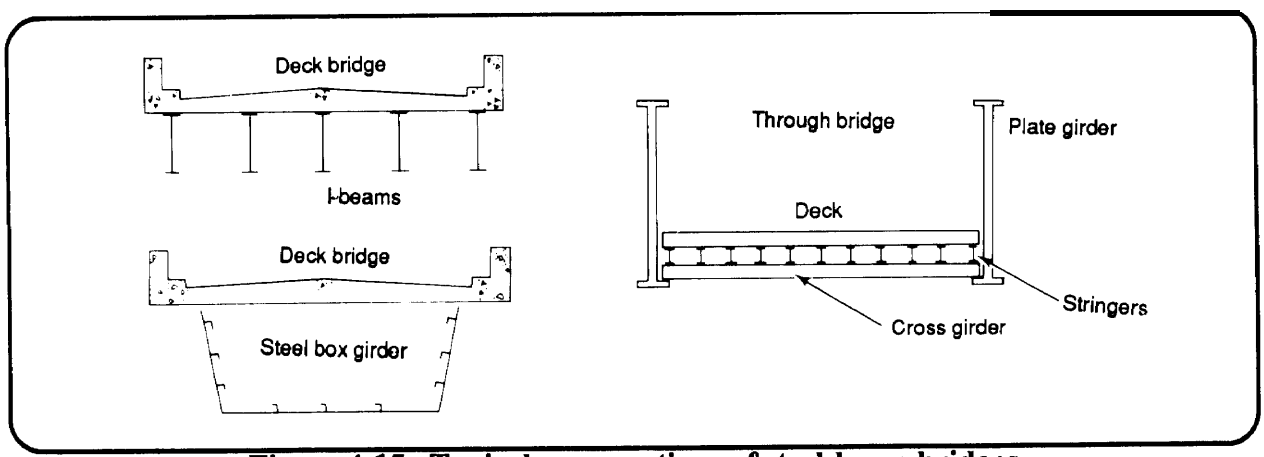


Figure 4-15. Typical cross sections of steel-beam bridges

(2) Steel-Truss Bridges. Figure 4-16 shows the side elevations for three normal steel-truss spans. Note that *all* truss bridges have diagonal members in the trusses.

(3) Concrete-Beam-and-Slab Bridges. For categorization purposes, you will not need to distinguish between reinforced- and prestressed-concrete bridges, as the methods of attack are the same for both. Figure 4-17 shows midspan cross-sectional views of these types of bridges. At midspan, the majority of steel reinforcing rods or tendons are located in the bottom portion of the superstructure. The attack methods detailed in Appendix H take this reinforcing condition into account.

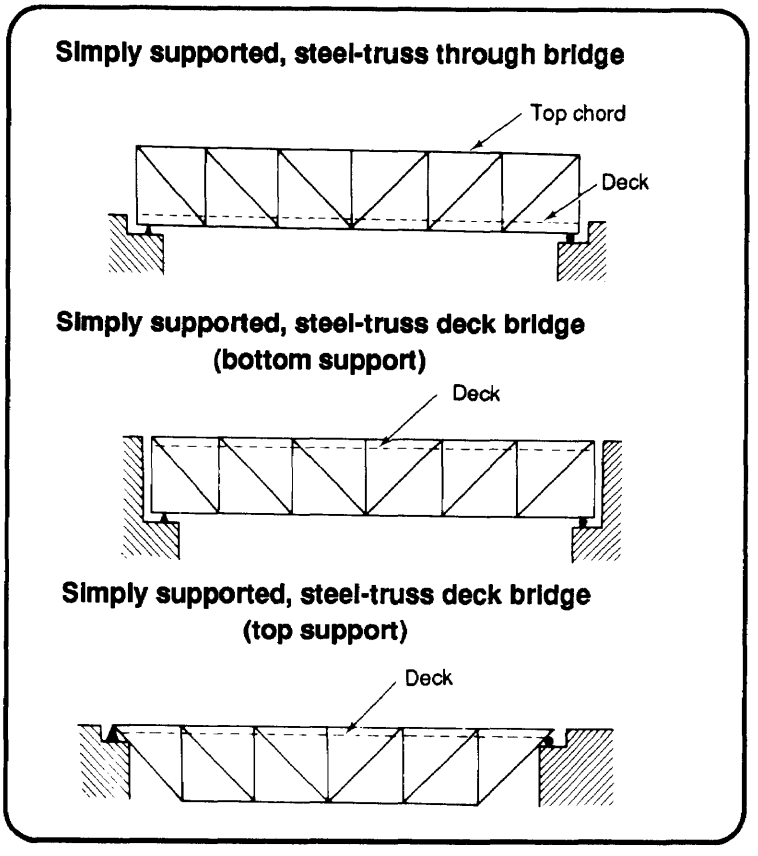


Figure 4-16. Side elevation of steel-truss bridges

(4) Bowstring Bridges. Note the following about bowstring bridges:

(a) Features. Figure 4-18 (page 4-12) shows the features of a normal bowstring bridge. Recognize that—

- The bow is in compression.
- The bow may be a steel beam, box girder, concrete beam, or steel truss. The bow's depth (thickness) is larger than or equal to the depth of the deck support members.
- The deck acts as a tie and resists the outward force applied by the bow.
- The deck is designed as a weak beam supported by the hangers.
- There is no diagonal bracing between the hangers.

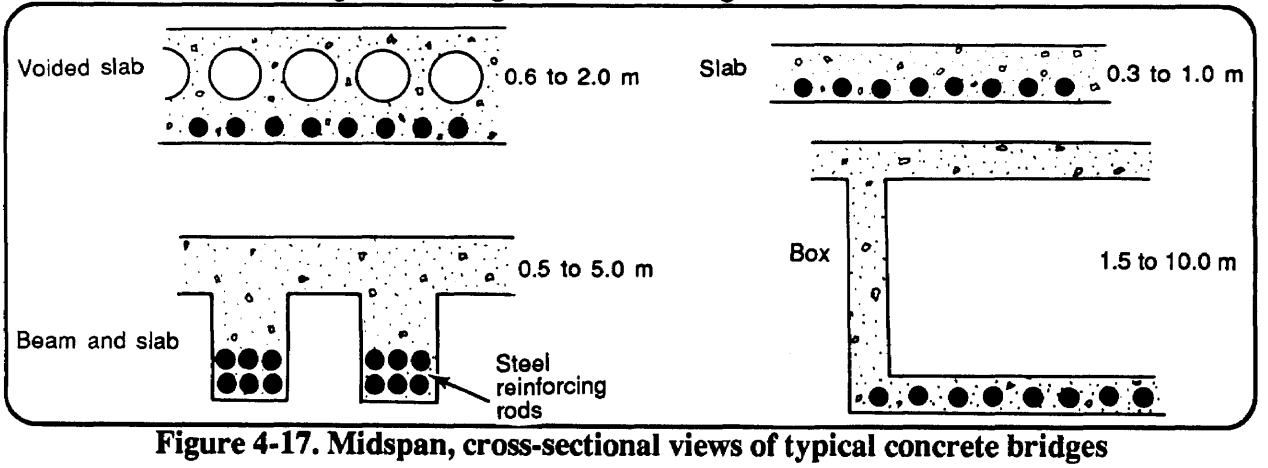


Figure 4-17. Midspan, cross-sectional views of typical concrete bridges

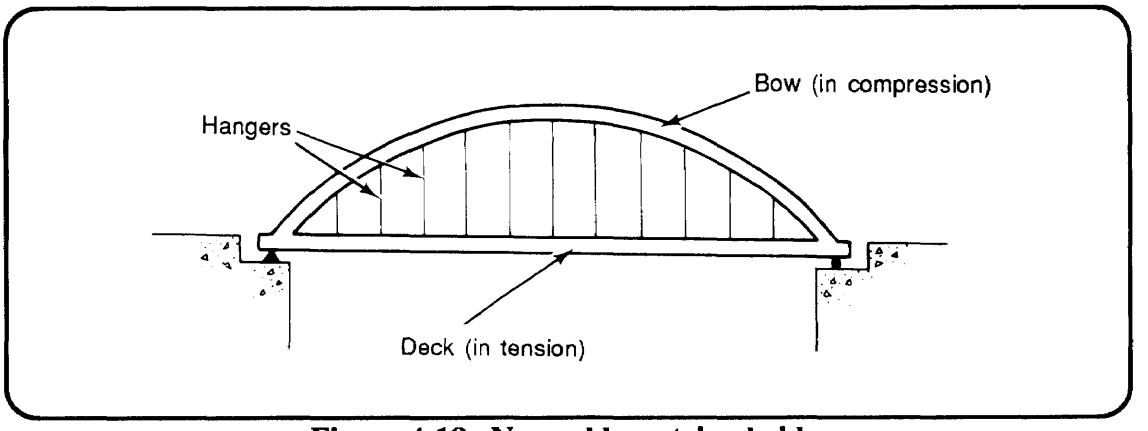


Figure 4-18. Normal bowstring bridge

(b) Uses. Occasionally the bow and hangers are used to reinforce a steel-beam or-truss bridge. Categorize this type of bridge as a bowstring reinforced-beam or -truss bridge (Figure 4-19). In this type of bridge, the depth (thickness) of the bow will always be less than the depth of the deck support members.

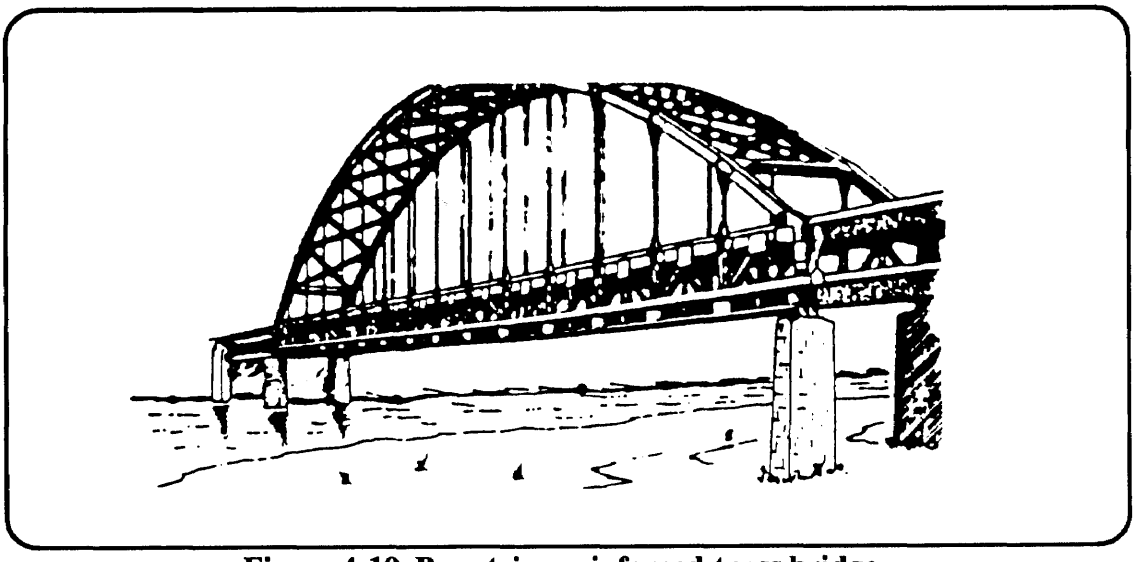


Figure 4-19. Bowstring reinforced-truss bridge

(c) Pseudo-bowstring bridges. The bridge illustrated in Figure 4-20 is not a bowstring, but an arch bridge. Categorize this type of bridge as an arch bridge because the outward forces of-the arch (pseudo bow) are restrained primarily by the abutments, not the deck.

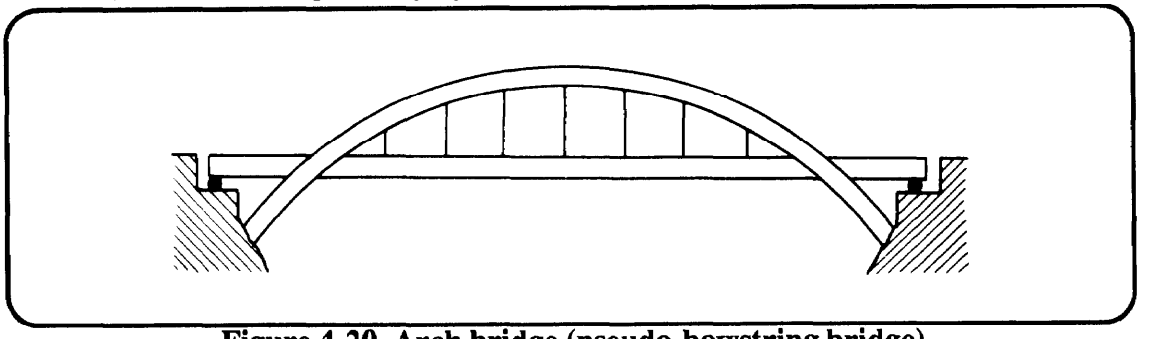


Figure 4-20. Arch bridge (pseudo-bowstring bridge)

b. *Reconnaissance.* For simply supported bridges, use the following reconnaissance procedure:

(1) Categorize the bridge.

(2) Measure the bridge (Figure 4-21):

(a) Length *(L).* Measure the length of the span to be attacked, in meters.

NOTE: This distance is not the clear gap, but the length of the longitudinal members that support the deck from end to end.

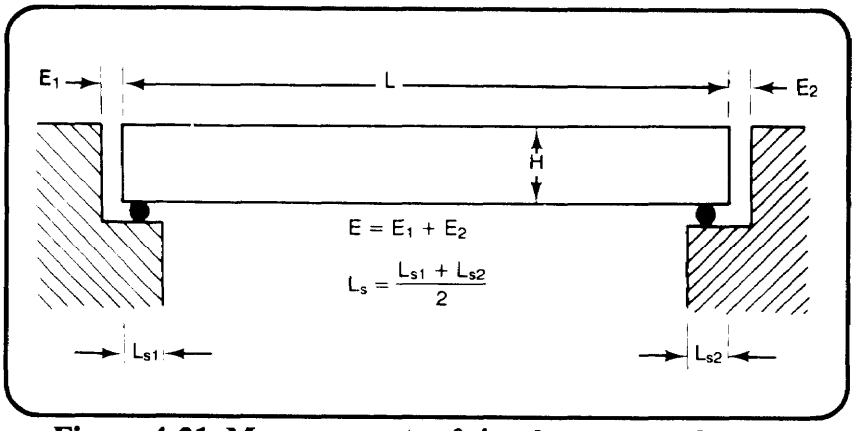


Figure 4-21. Measurements of simply supported spans

(b) Depth *(H).* Measure the depth of the beam, truss, or bow, in meters (include the deck with the beam or truss measurement).

(c) Total end clearance *(E).* Total the amount of end clearance at both ends of the span, in meters.

(d) Average length of the bearing supports *(L_s).* Measure the average length of the bearing supports from the ends of the spans to the faces of the abutments or piers, in meters.

(3) Determine the attack method (Appendix H).

(4) Determine the critical dimensions of the span required for charge calculations.

c. *Attack.* Two considerations apply when attacking a simply supported span:

(1) Point of Attack. Attack simply supported bridges at or near midspan, because—

- Bending moments are maximum at midspan.
- The likelihood of jamming during collapse is reduced if the bridge is attacked at midspan.

(2) Line of Attack. Make the line of attack parallel to the lines of the abutments (Figure 4-22). Doing this reduces the risk that the two parts of the span will slew in opposite directions and jam. Do not employ any technique that induces twist in the bridge. If the line of attack involves cutting across transverse beams, reposition the line of attack to cut between the transverse beams.

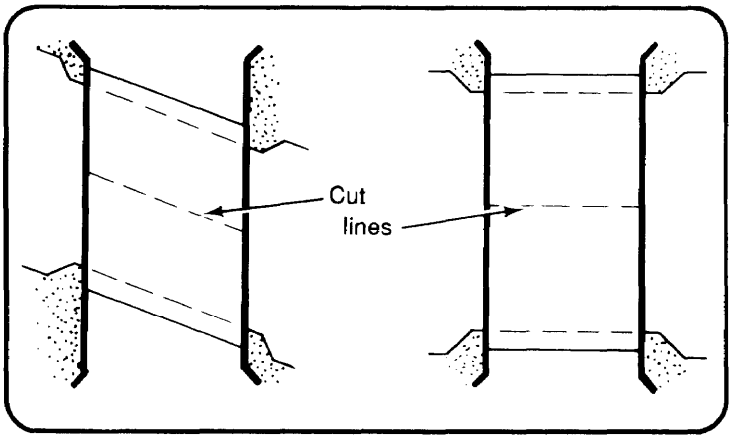


Figure 4-22. Line of attack

d. *Attack Methods.* Table H-3 (page H-3) lists in recommended order, attack methods likely to produce the most economical demolition, by bridge category. Within each category are variations to accommodate differences in construction materials, span configurations, load capacities (road, rail, or both), and gap and abutment conditions. The three recommended ways of attacking simply supported spans are bottom, top, and angled attacks. In all cases, ensure jamming cannot occur during collapse.

(1) Bottom Attack. Use the bottom attack whenever possible, as it leaves the roadway open and enables you to use the bridge, even when the demolitions are at a ready-to-fire state (State 2). Reinforced and prestressed (tension) beams are very vulnerable to bottom attack, as the steel cables and reinforcing bars run along the bottom portion of the beam and are thus covered by less concrete. The major disadvantages of the bottom attack are the increased amount of time and effort necessary for placing and inspecting the charges. Because it is generally impracticable to place sufficient explosive below a reinforced or prestressed slab to guarantee a cut deeper than 0.15 meters, used the top or angled attacks listed in Table H-3 (page H-3) for these types of bridges. When Table H-3 (page H-3) lists a bottom attack, determine the required end clearance *(ER)* from Table H-1 (page H-1) to prevent jamming. If the total end clearance *(E)* is greater than *ER*, jamming will not occur. If *E* is less than *ER*, use a top or angled attack or destroy one abutment at the places where jamming would occur. Example A-13 (page A-12), explains the method for bottom attack calculations.

(2) Top Attack. When Table H-3 (page H-3) lists a top attack, L_C must be removed from the top of the bridge to prevent jamming. Determine L_C from Table H-2 (page H-2). Remove L_C in a V-shaped section along the full depth of the target. For reinforced-concrete bridges, use a concrete-stripping charge (paragraph 4-9, page 4-7) to remove L_C from the top of the bridge. This action, by itself, should cause collapse. There is no requirement to cut steel reinforcing rods. Example A-14 (page A-13) shows the method for top attack calculations.

(3) Angled Attack. For angled attacks, cut all members (span, hand-rails, service pipes, and so forth) of the bridge. Make the angle of attack approximately 70 degrees to the horizontal to prevent jamming. The location of the charge should be between the midspan point and a point *L/3* from the end (Figure 4-23). Although an angled attack is effective on any type of bridge, it is essential when the bridge must be kept open to traffic, or when there is ample time to prepare demolitions.

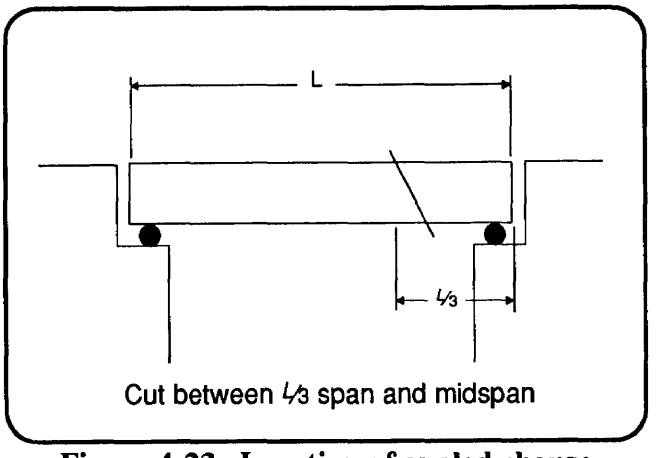


Figure 4-23. Location of angled charge

4-12. Continuous Bridges.

a. *Categorization.* Figure 4-24 is a categorization chart for continuous bridges. Use this chart like the chart for simply supported bridges. There are six main subcategories: cantilever, cantilever and suspended span, beam or truss, portal, arch, and masonry arch. The first five categories differentiate between steel and concrete construction, as each material has a different attack method. If a continuous bridge is of composite construction (for example, steel beams supporting a

reinforced-concrete deck), the material that comprises the main, longitudinal load-bearing members will determine the attack method.

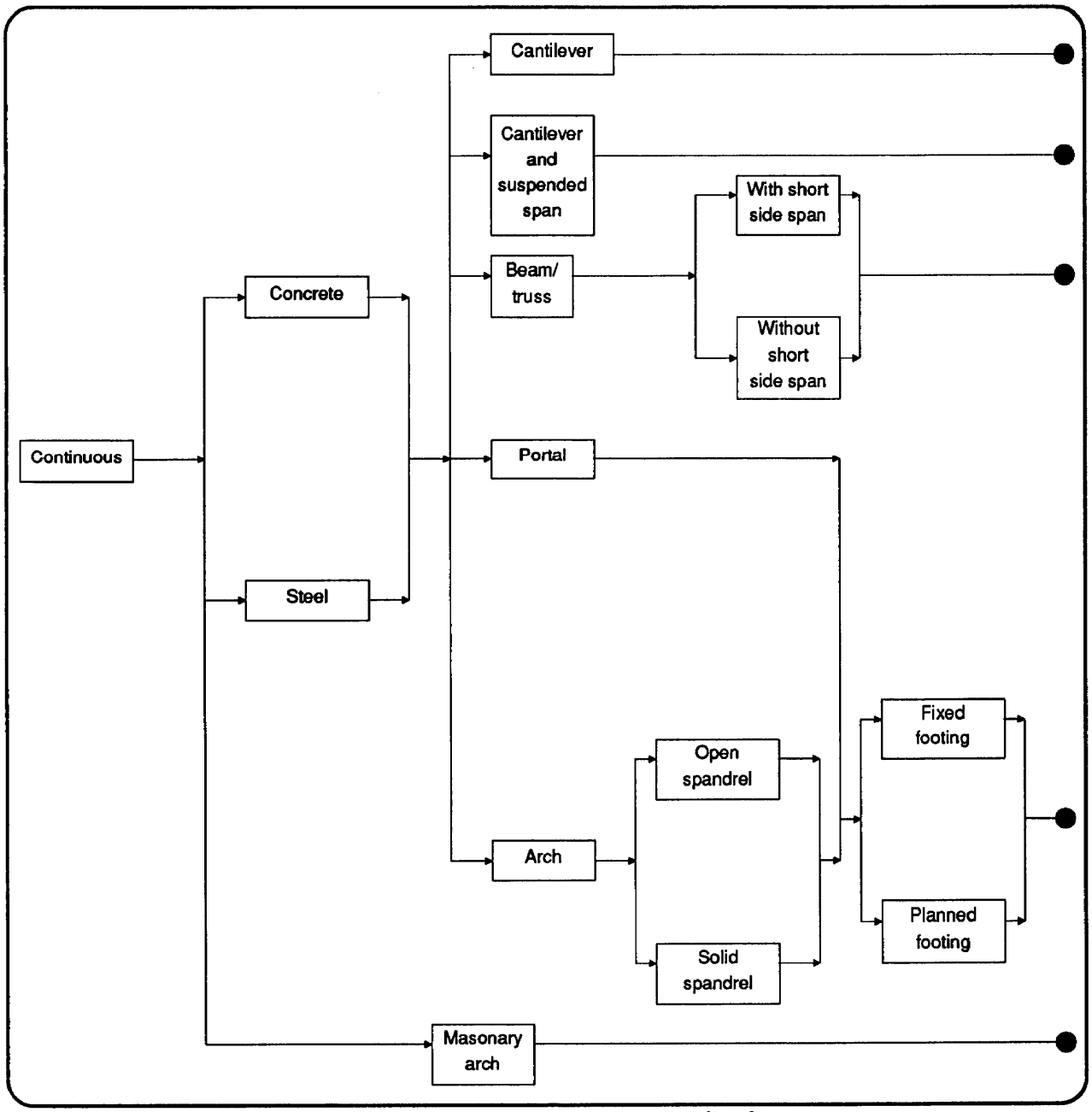


Figure 4-24. Continuous-bridges categorization chart

(1) Cantilever Bridges. A cantilever bridge (Figure 4-25, page 4-16) has a midspan shear joint. Note that the full lengths of the anchor spans may be built into the abutments, making the cantilever difficult to identify.

(2) Cantilever and Suspended-Span Bridges. If a cantilever bridge incorporates a suspended span (Figure 4-26, page 4-16) that is at least 5 meters longer than the enemy assault bridging capability, attack this section of the bridge; attacking this section requires less preparation. Because

suspended spans are simply supported, use the attack method described for simply supported bridges (Table H-3, page H-3).

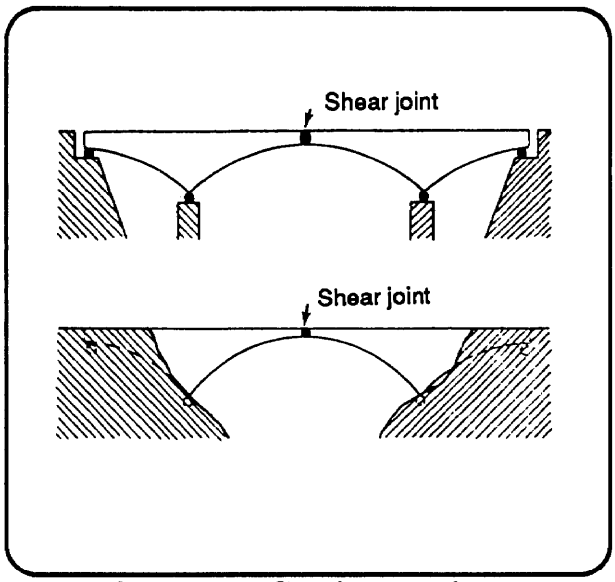


Figure 4-25. Cantilever bridges

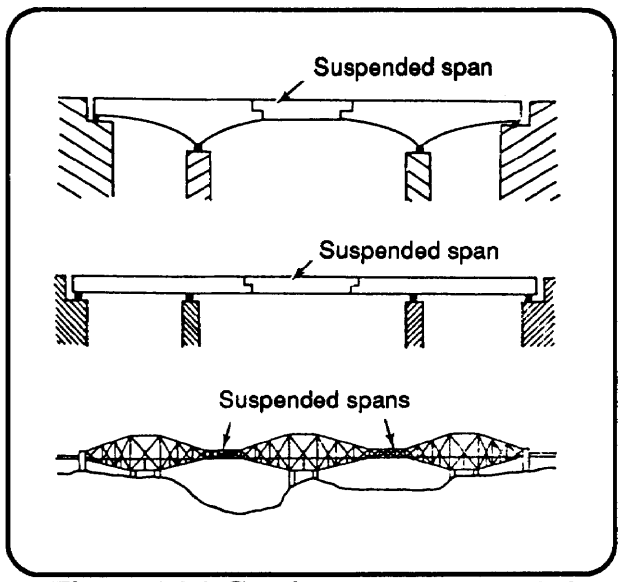


Figure 4-26. Cantilever and suspended span bridges

(3) Beam or Truss Bridges. For beam or truss bridges (Figures 4-27 through 4-29), differentiate between those bridges with spans of similar lengths and those with short side spans because this affects the attack method. A short side span is one that is less than three quarters of the length of the next adjacent span.

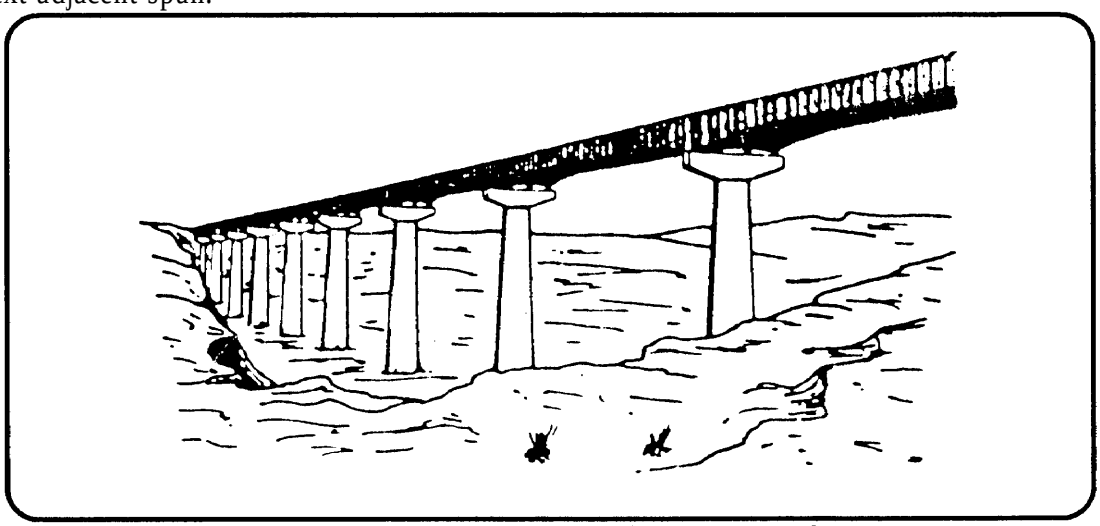


Figure 4-27. Steel-beam bridge without short side span

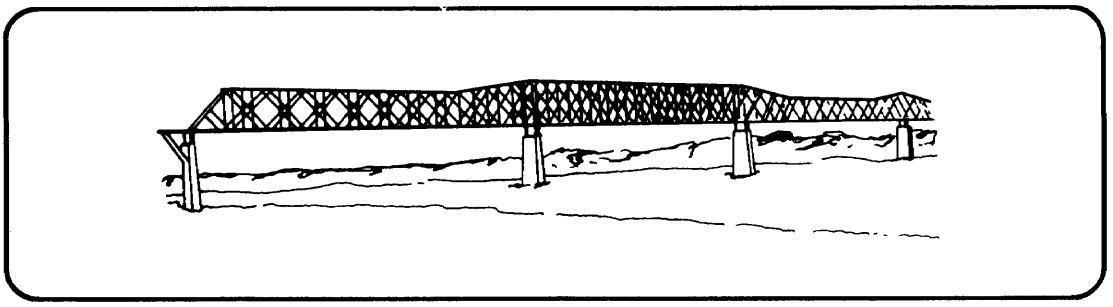


Figure 4-28. Steel-beam bridge with short side span

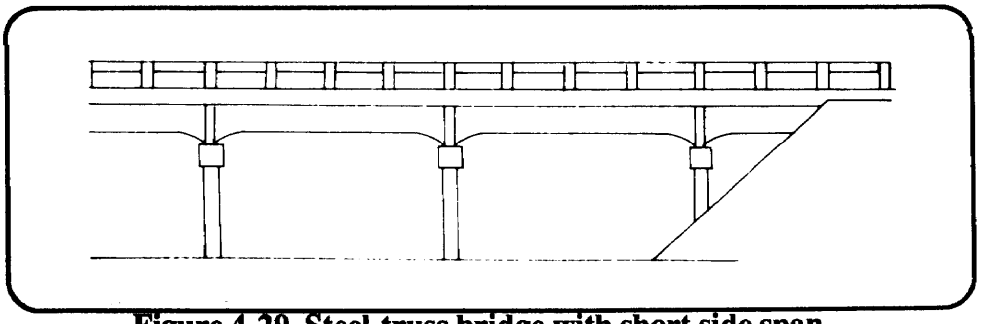


Figure 4-29. Steel-truss bridge with short side span

(4) Portal Bridges. For portal bridges (Figure 4-30), differentiate between those with fixed footings and those with pinned footings, as this affects the attack method. If you cannot determine the type of footing, assume fixed footings. Portal bridges, as opposed to arch bridges, lack a smooth curve between the bearing point of the span and the span itself.

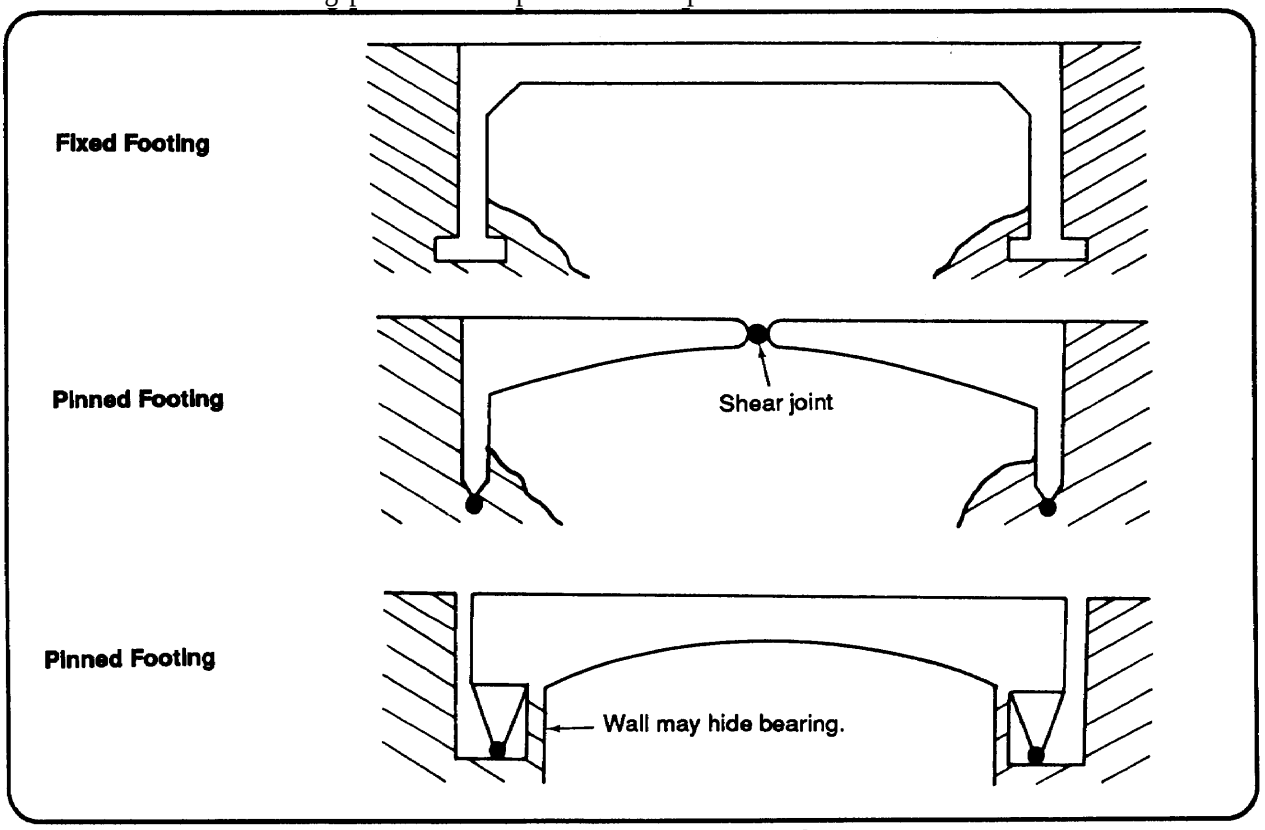


Figure 4-30. Typical portal bridges

(5) Arch Bridges. In arch bridges (Figure 4-31), determine whether the bridge has an open or solid spandrel and fixed or pinned footings. Again, when in doubt, assume fixed footings.

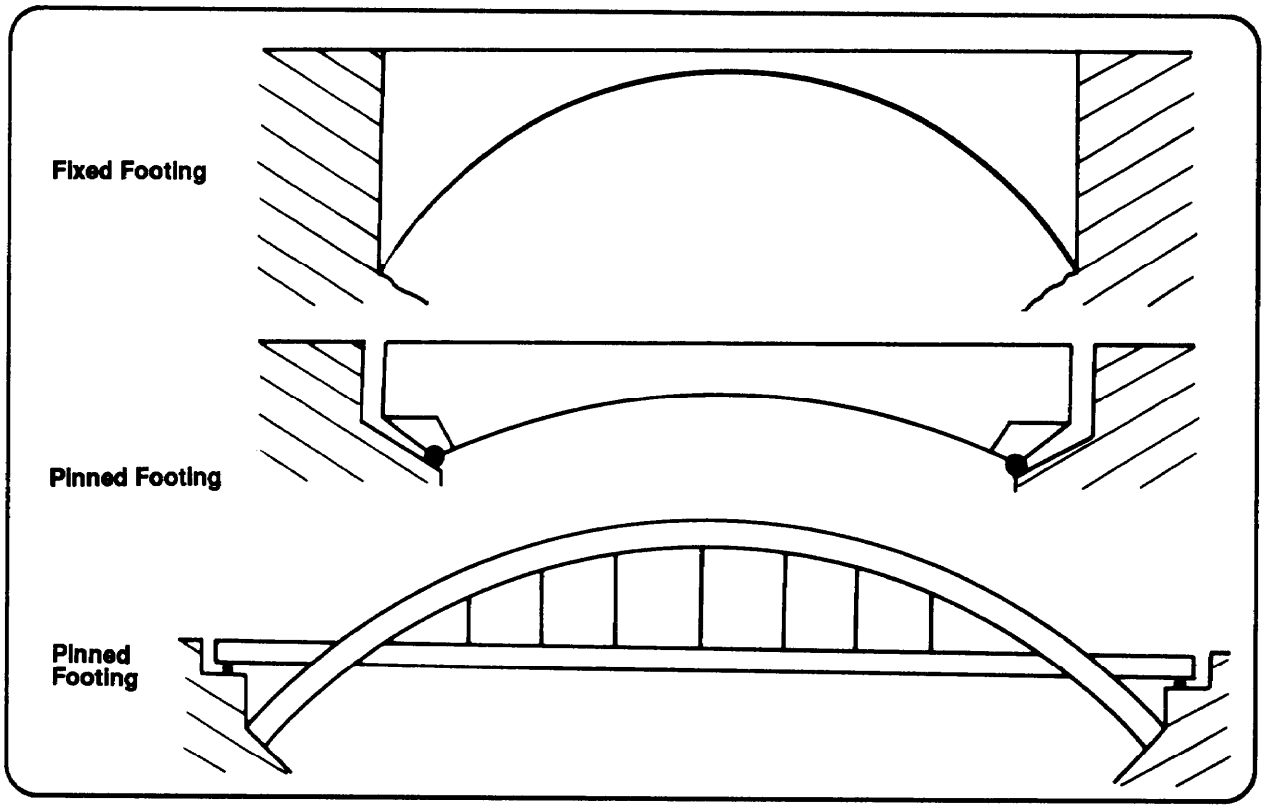


Figure 4-31. Arch bridges

(6) Masonry Arch Bridges. Identify masonry arch bridges (Figure 4-32) by their segmental arch ring. However, it is easy to mistake a reinforced-concrete bridge for a masonry-arch bridge because many reinforced-concrete bridges have masonry faces. Always check the underside of the arch. The underside is rarely faced on reinforced-concrete bridges.

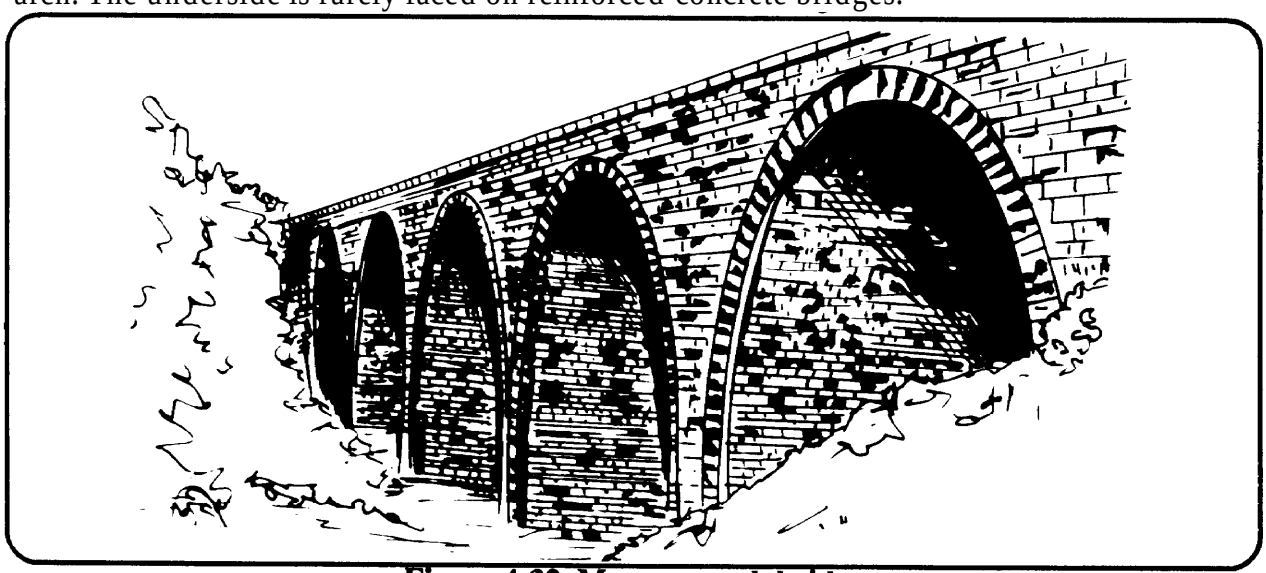


Figure 4-32. Masonry arch bridge

b. *Reconnaissance.* For continuous bridges, use the following reconnaissance procedure:

(1) Categorize the bridge.

(2) Measure the bridge (Figure 4-33):

(a) Length *(L).* Measure the span you plan to attack, in meters (between centerlines of the bearings).

(b) Rise *(H).* For arch and portal bridges, measure the rise, in meters (from the springing or bottom of the support leg to the deck or top of the arch, whichever is greater).

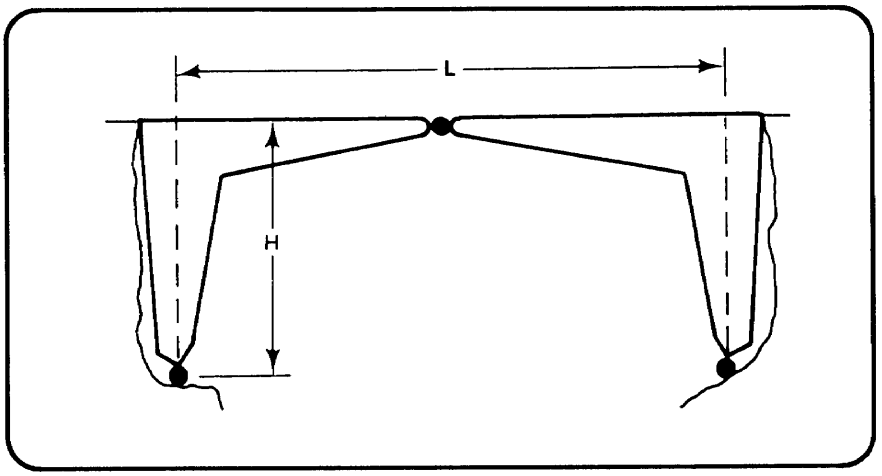


Figure 4-33. Measurements of continuous bridges

(c) Determine the attack method from Appendix H.

(d) Determine the critical dimensions necessary for charge calculations.

c. *Bridge Attacks.* As with simply supported spans, two considerations apply when attacking continuous spans: the point of attack and line of attack. No common point-of-attack rule exists for all categories of continuous bridges, but the line-of-attack rule applies to *all* continuous bridges. That is, the line of attack must be parallel to the lines of the abutments, and twisting must not occur during the demolition. If the recommended line of attack involves cutting across transverse beams, reposition the line to cut between adjacent transverse beams. Table H-4 (page H-7) lists attack methods for continuous spans.

(1) Steel Bridges. When attacking continuous-span steel bridges, use the see-saw or unsupported-member collapse mechanism. Both mechanisms produce complete cuts through the span. Providing you can properly place charges, you may be able to demolish these bridges with a single-stage attack. However, on particularly deep superstructures (concrete decks on steel beams), charges designed to sever the deck may not cut through all of the reinforcing steel. Therefore, during reconnaissance, always plan for the possibility of a two-stage attack on deep, composite superstructures. Make angle cuts at about 70 degrees to the horizontal to prevent jamming during collapse.

(2) Concrete Bridges. Continuous concrete bridges are the most difficult to demolish and hence are poor choices for reserved demolitions. Even when construction drawings are available and there is ample time for preparation, single-stage attacks are rarely successful. Consider using a bottom attack for this bridge type.

(3) Arch and Portal Bridges. For arch bridges and portal bridges with pinned footings, collapse can be guaranteed only be removing a specified minimum span length. Determine this minimum length by using Table 4-1 (page 4-20) and the *L* and *H* values determined by reconnaissance. Example A-15 (page A-14) explains the method for arch bridge attack calculations.

Table 4-1. Minimum L_c values for arch and pinned-footing bridge attacks

$\frac{H}{L}$	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200
$\frac{L_c}{L}$	0.003	0.007	0.013	0.020	0.030	0.040	0.053	0.067	0.083
$\frac{H}{L}$	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360	
$\frac{L_c}{L}$	0.100	0.130	0.150	0.170	0.200	0.230	0.270	0.300	

NOTES:

1. The values in this table are based on the following formula:

$$\frac{L_c}{L} = 1 - [1 - 4(\frac{H}{L})^2]^{1/2}$$

2. If the result of $\frac{H}{L}$ is not on the chart exactly as calculated, round UP to the next higher value on the chart. For example, if $\frac{H}{L} = 0.089$, use the column headed 0.10 to determine $\frac{L_c}{L}$. In this case, $\frac{L_c}{L} = 0.02$. Multiply the $\frac{L_c}{L}$ value by L to get L_c. For example, $0.02 \times L = L_c$.

4-13. Miscellaneous Bridges.

a. *Suspension-Span Bridges.* Suspension-span bridges usually span very large gaps. These bridges have two distinguishing characteristics: roadways carried by flexible members (usually wire cable) and long spans (Figure 4-34).

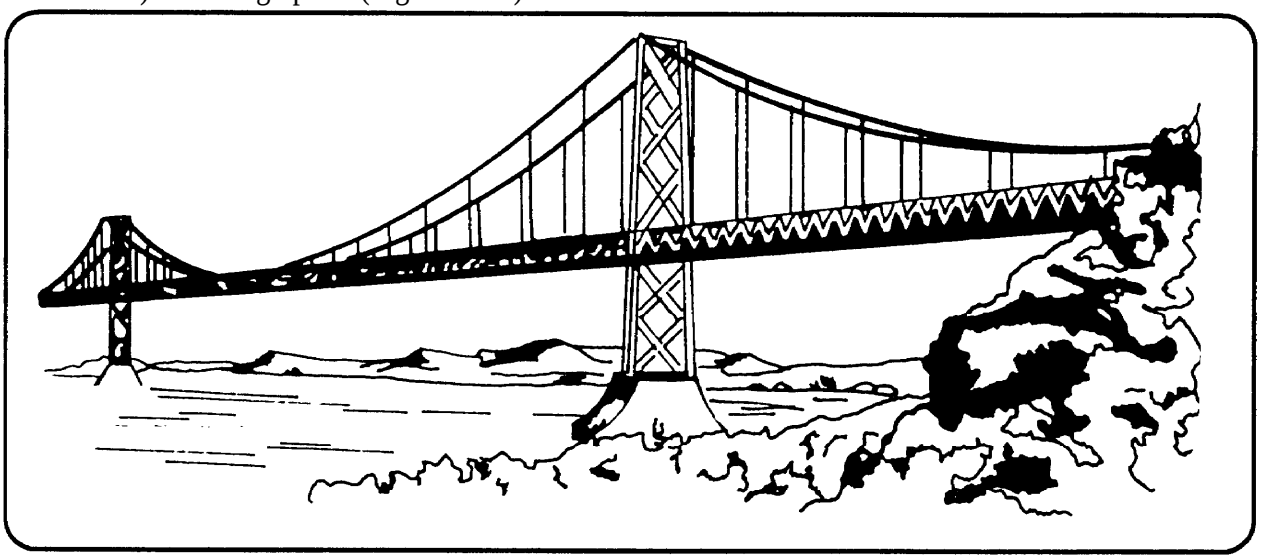


Figure 4-34. Suspension-span bridge

(1) Components. The components of suspended-span bridges are cables, towers, trusses or girders, and anchors. Suspension-bridge cables are usually multiwire-steel members that pass over the tower tops and terminate at anchors on each bank. The cables are the load-carrying members. (The Golden Gate bridge has 127,000 miles of wire cable of this type.) The towers support the cables. Towers may be steel, concrete, masonry, or a combination of these materials. The trusses or girders do not support the load directly; they only provide stiffening. Anchors hold the ends of the cables in place and may be as large as 10,000 cubic feet.

(2) Demolishing Methods.

(a) Major bridges. Anchors for major suspension bridges are usually too massive to be demolished. The cables are usually too thick to be effectively cut with explosives. The most economical demolition method is to drop the approach span or a roadway section by cutting the suspenders of the main or load-bearing cables. The enemy's repair and tactical bridging capabilities determine the length of the target section. When reinforced-concrete towers are present, it may be feasible to breach the concrete and cut the steel of the towers.

(b) Minor bridges. The two vulnerable points on minor suspension bridges are towers and cables. Use the following methods:

- Towers. Destroy towers by placing tower charges slightly above the level of the roadway. Cut a section out of each side of each tower. Place the charges so that they force the ends of the cut sections to move in opposite directions, twisting the tower. Doing this will prevent the end of a single cut from remaining intact. Demolition chambers, provided in some of the newer bridges, make blasting easier, quicker, and more effective.
- Cables. Destroy the cables by placing charges as close as possible to anchor points, such as the top of towers. Cables are difficult to cut because of the air space between the individual wires in the cable. Ensure the charge extends no more than one half the cable's circumference. These charges are usually bulky, exposed, and difficult to place. Shaped charges are very effective for cable cutting.

b. *Movable Bridges.* These bridges have one or more spans that open to provide increased clearance for waterway traffic. The three basic types of movable bridges are swing-span, bascule, and vertical-lift. The characteristics of these bridges are described in the next paragraphs.

(1) Swing-Span Bridges.

(a) Characteristics. A swing span is a continuous span capable of rotating on a central pier. The arms of a swing-span bridge may not be of equal length. If the arms are not of equal length, weights are added to balance them. Rollers that run on a circular track on top of the central pier carry the span's weight. The swing span is independent from any other span in the bridge. Identify a swing-span bridge by its wide, central pier. This central pier is much wider than the one under a continuous-span bridge that accommodates the rollers and turning mechanism (Figure 4-35).

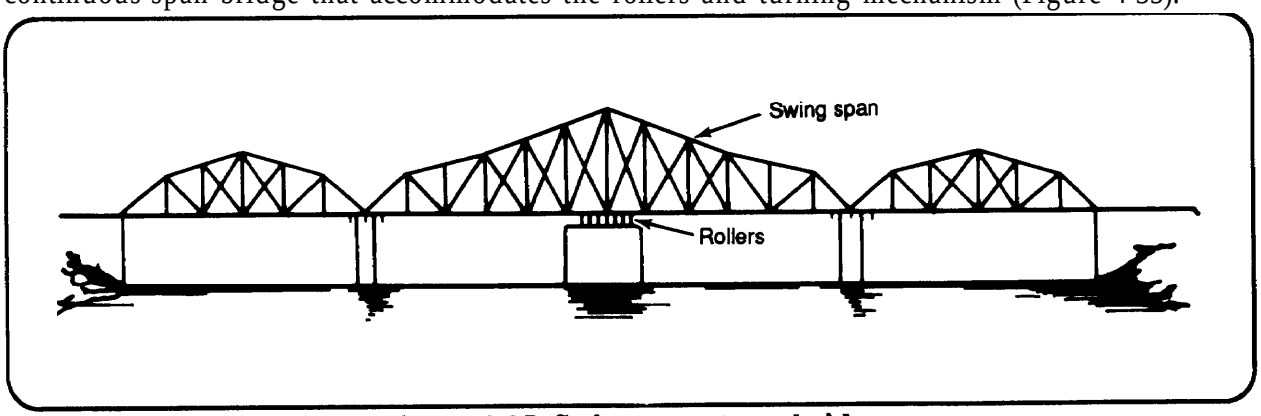


Figure 4-35. Swing-span truss bridge

(b) Demolition methods. Because swing-span bridges are continuous bridges, use an attack method from the continuous bridge section in Appendix H. For partial demolition, open the swing span and damage the turning mechanism.

(2) Bascule Bridges.

(a) Characteristics. Bascule bridges are more commonly known as drawbridges. These bridges usually have two leaves that fold upward (Figure 4-36), but some bascule bridges may have only one leaf (Figure 4-37). The movable leaves in bascule bridges appear in three general forms: counterweights below the road level (most modem), counterweights above the road level (older type), and no counterweights (lifted by cable or rope; oldest type; usually timber).

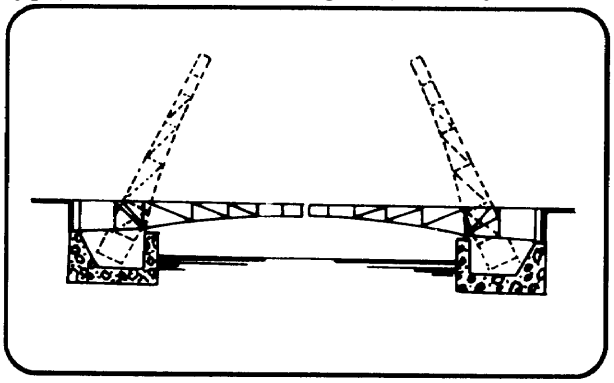


Figure 4-36. Double-leaf bascule bridge

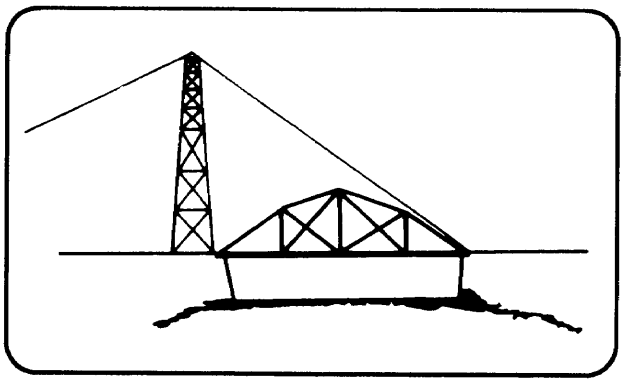


Figure 4-37. Single-leaf bascule bridge

(b) Demolition methods. Demolish the cantilever arms with an attack method appropriate for simply supported bridges. For partial demolition, open the bridge and jam or destroy the lifting mechanism.

(3) Vertical-Lift Bridges.

(a) Characteristics. These bridges have simply supported, movable spans that can be raised vertically in a horizontal position. The span is supported on cables that pass over rollers and connect to large, movable counterweights (Figure 4-38).

(b) Demolition methods. Demolish the movable span with an attack method appropriate for simply supported bridges. Another method is to raise the bridge and cut the lift cables on one end of the movable span. The movable span will either wedge between the supporting towers or fall free and severely damage the other tower.

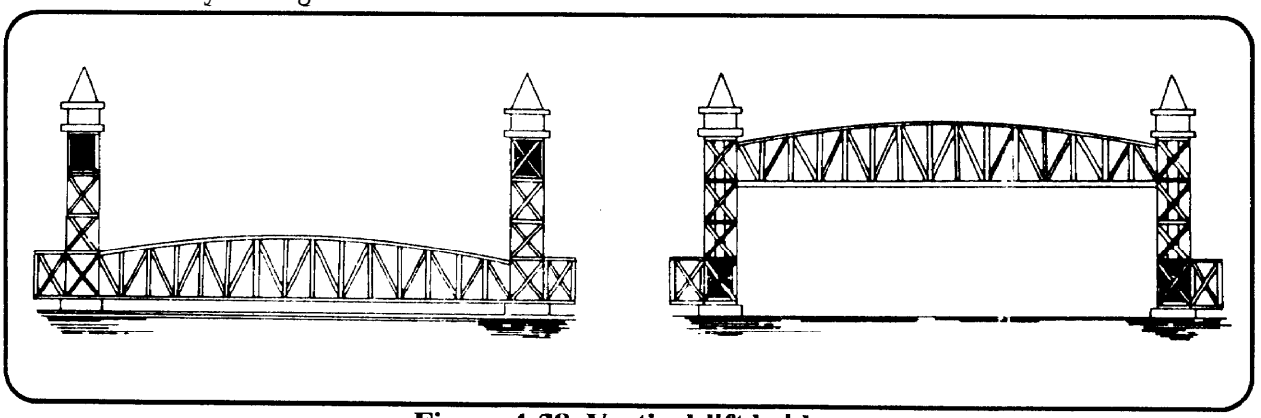


Figure 4-38. Vertical-lift bridge

(4) Floating Bridges. Floating bridges consist of a continuous metal or wood roadway supported by floats or pontoons (Figure 4-39).

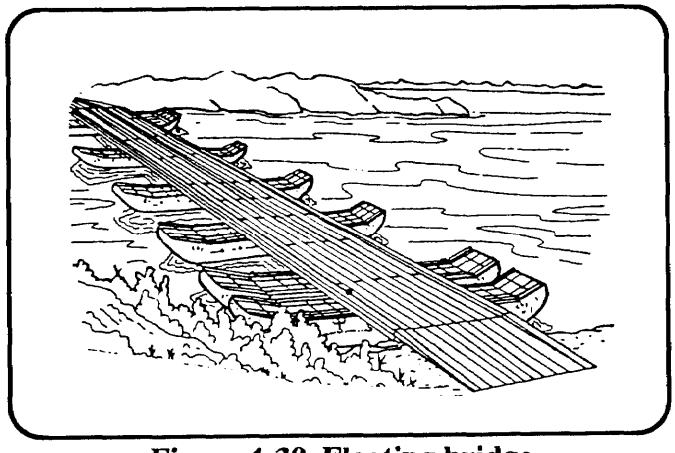


Figure 4-39. Floating bridge

(a) Pneumatic floats. Pneumatic floats are airtight compartments of rubberized fabric inflated with air. For hasty attack of these bridges, cut the anchor cables and bridle lines with axes and the steel cables with explosives. Also, puncture the floats with small-arms or machine-gun fire. Using weapons to destroy the floats requires a considerable volume of fire because each float has a large number of watertight compartments. Another method is to make a clean cut through the float, using detonating cord stretched snugly across the surface of the pontoon compartments. One strand of cord is enough to cut most fabrics, but two strands may be necessary for heavier materials. Also, place one turn of a branch-line cord around each inflation valve. This will prevent the raft from being reinflated if it is repaired. Do not use main-line cords to cut valves because the blast wave may fail to continue past any sharp turn in the cord.

b) Rigid pontoons. Rigid pontoons are made of various materials: wood, plastic, or metal. To destroy these bridges, place a ½-pound charge on the upstream end of each pontoon at water level. Detonate all charges simultaneously. If the current is rapid, cut the anchor cables so that the bridge will be carried downstream. Another method is to cut the bridge into rafts. Place ½-pound charges at each end of each pontoon and detonate them simultaneously. To destroy metal treadways on floating bridges, use the steel-cutting formula (paragraph 3-6, page 3-8). The placement and size of the charges depend on bridge type. Typically, placing cutting charges at every other joint in the treadway will damage the bridge beyond use.

(5) Bailey Bridges. To destroy these bridges, place l-pound charges between the channels of the upper and lower chords. Use ½-pound charges for cutting diagonals and l-pound charges for cutting sway bracing (Figure 4-40).

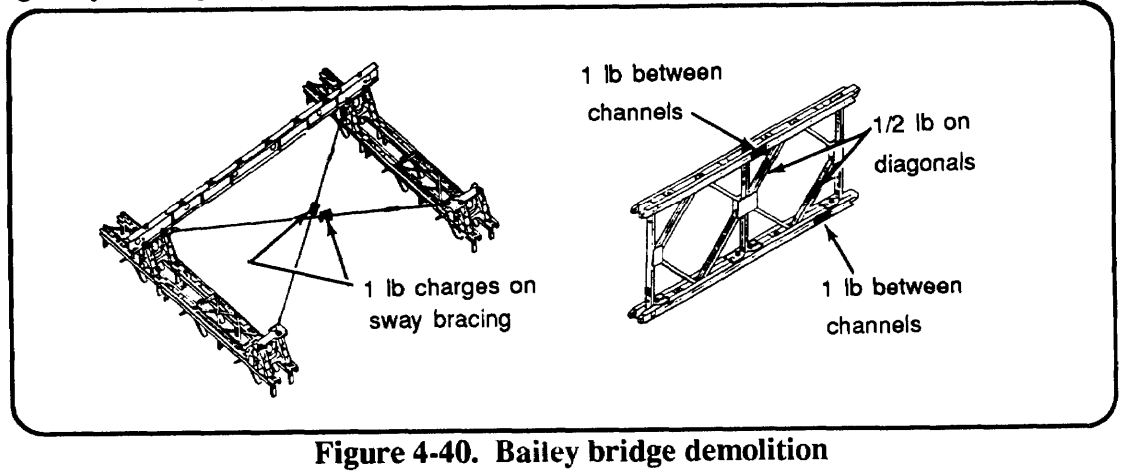


Figure 4-40. Bailey bridge demolition

(a) In-place demolitions. Cut the bridge in several sections by attacking the panels on each side, including the sway bracing. The angle of attack should be 10 degrees to the horizontal to prevent jamming. In double-story or triple-story bridges, increase the charges on the chords at the story-junction line. For further destruction, place charges on the transoms and stringers.

(b) In-storage or-stockpile demolition. When abandoning bridges in storage, do not leave any component the enemy can use as a unit or for improvised construction. Do this by destroying the essential components that the enemy cannot easily replace or manufacture. Panel sections fulfill the role of essential components. To render the panel useless, remove or distort the female lug in the lower tension chord. Destroy all panels before destroying other components.

Section III. Abutments and Intermediate Supports

4-14. Abutments. To demolish abutments, place charges in the fill behind the abutment. This method uses less explosive than external breaching charges and also conceals the charges from the enemy. The disadvantage is the difficulty in placing the charges. When speed is required, do not place charges behind abutments if you know the fill contains large rocks.

a. *Abutments (5 Feet Thick or Less).* Demolish these abutments by placing a line of 40-pound cratering charges, on 5-foot centers, in boreholes 5 feet deep, located 5 feet behind the face of the abutment *(triple-nickel-forty method).* Place the first hole 5 feet from either end of the abutment and continue this spacing until a distance of 5 feet or less remains between the last borehole and the other end of the abutment (Figure 4-41). If the bridge approach is steep, place the breaching charges against the rear of the abutment. Determine the number of 40-pound cratering charges as follows:

$$N = \frac{W}{5} - 1 \qquad \textbf{(4-3)}$$

where—

N = number of charges; round UP to next higher whole number.
W = abutment width, in feet.

b. *Abutments (0ver 5 Feet Thick).* Destroy these abutments with breaching charges in contact with the back of the abutment. Calculate the amount of each charge using the breaching formula in equation 3-6 (page 3-16). Use the abutment thickness as the breaching radius. Determine the number of charges and their spacing using equation 3-7 (page 3-19). Place charges at least three feet below the bridge seat (where the bridge superstructure sits on the abutment) (Figure 4-42).

c. *Abutments (Over 20 Feet High).* Demolish these abutments by placing a row of breaching charges at the base of the abutment on the gap side, in addition to the charges specified in paragraphs 4-14a or 4-14b above. Fire all charges simultaneously. This method tends to overturn and completely destroy the abutment.

d. *Wing Walls.* If the wing walls can support a rebuilt or temporary bridge, destroy the wing walls by placing charges behind them in the same manner as for abutments (Figures 4-41 and 4-42).

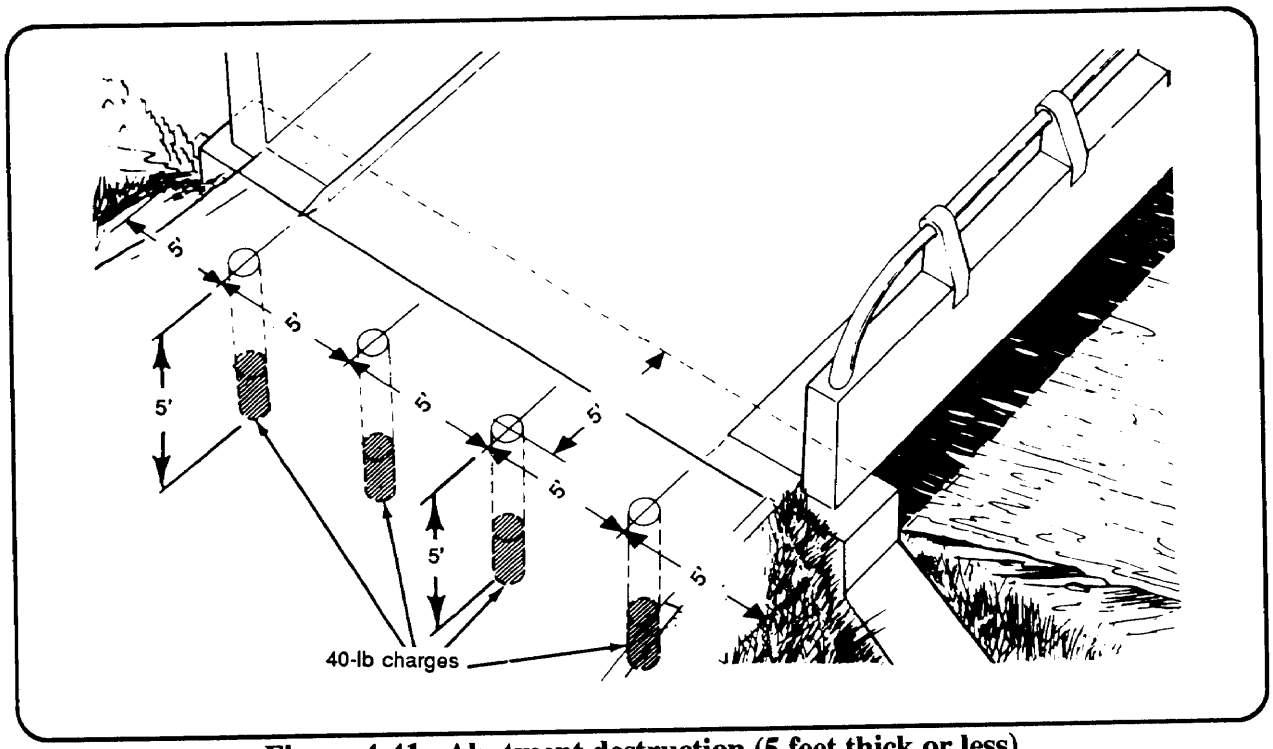


Figure 4-41. Abutment destruction (5 feet thick or less)

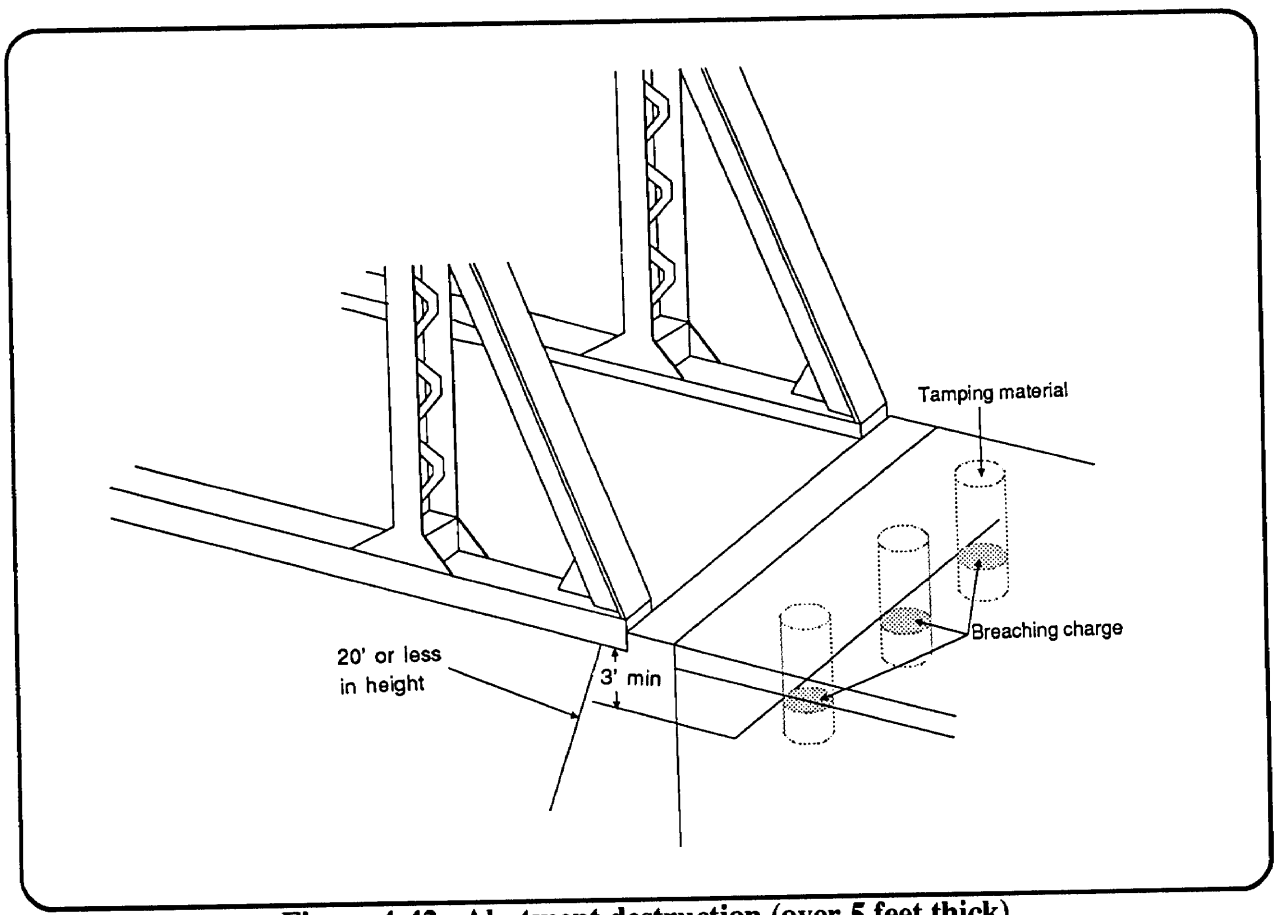


Figure 4-42. Abutment destruction (over 5 feet thick)

4-15. Intermediate Supports. Demolish concrete and masonry piers with internal or external charges (Figure 4-43).

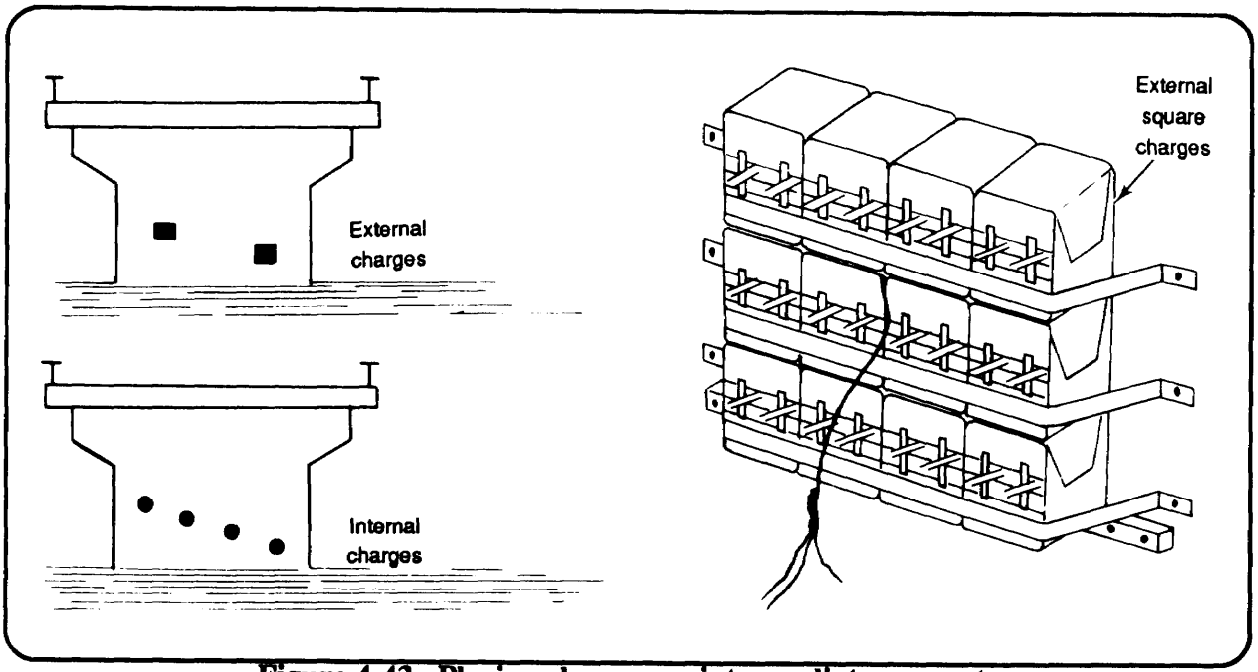


Figure 4-43. Placing charges on intermediate supports

a. *Internal Charges.* These charges require less explosive than do external charges. However, unless the support has built-in demolition chambers, this method requires an excessive amount of equipment and preparation time. Use equation 3-6 (page 3-16) to determine the amount of each charge. Ml12 (C4) is ideal for internal charges. Thoroughly tamp all charges of this type with nonsparking tools (blunt, wooden tamping sticks or similar tools). If the support has demolition chambers, place the charges in boreholes created with shaped charges or drilled with pneumatic or hand tools. A 2-inch-diameter borehole holds approximately 2 pounds of explosive per foot of depth. The steel reinforcing bars, however, make drilling in heavily reinforced concrete impractical.

b. *External Charges.* Place these charges at the base of the pier or higher, and do not space the charges by more than twice the breaching radius. Stagger the charges to leave a jagged surface to hinder future use. Thoroughly tamp all external charges with earth and sandbags, if time, size, shape, and location of the target permit.

Chapter 5
Demolition Operations

This chapter implements STANAG 2017 (ENGR), STANAG 2123 (ENGR), QSTAG 508, and QSTAG 743.

Section I. Demolition Plan

5-1. Demolition Obstacles. Although engineers use explosives for quarrying, land clearing, and other projects, their most important military application is creating demolition obstacles. Engineers use demolition obstacles in conjunction with many other types of obstacles, including mines. They also use explosives to destroy materiel and facilities that must be abandoned (denial operations).

5-2. Barriers and Denial Operations. Division or higher-echelon commanders normally direct the use of extensive barriers and denial operations. Commanders must carefully prepare and closely coordinate these operations with all tactical plans. Engineer units provide technical advice and supervision, estimate the resources necessary for obstacle construction, construct barriers or obstacles, and recommend allocation of engineer resources. They usually construct demolition obstacles because they have the special skills and equipment to accomplish these tasks.

5-3. Demolition Planning. Base any demolition project on careful planning and reconnaissance. Use the following factors as a basis for selecting and planning demolition projects:

- Mission.
- Limitations and instructions from higher authority.
- Current tactical and strategic situation and future plans (conditions that indicate the length of time you must delay the enemy, the time available for demolition, and the extent of denial objectives).
- Enemy capabilities and limitations, as well as the effect our denial operations have on enemy forces, strategically and tactically.
- Likelihood that friendly forces may reoccupy the area, requiring obstacle neutralization.
- Economy of effort.
- Time, material, labor, and equipment available.
- Effect on the local population.
- Target protection required.

Section II. Types of Military Demolitions

5-4. Demolition Orders. The authorized commanders use the *Orders for the Demolition* to pass their orders to demolition guards and demolition firing parties. The Orders for the Demolition, as outlined in STANAG 2017 and QSTAG 508, is a standard four-page form used by North Atlantic Treaty Organization (NATO) and ABCA countries. Use this form for preparing all reserved and preliminary demolitions. Page one of the form contains the instructions, duties, and responsibilities of demolition personnel. A sample of the orders is included in the sample target folder in Appendix F (page F-4).

5-5. Preliminary Demolitions.

a. *Purpose.* Provided you have prior authority, detonate a preliminary demolition immediately after preparation. These demolitions present fewer difficulties to both commanders and engineers than do reserved demolitions. Commanders may restrict preliminary demolitions for tactical, political, or geographical reasons.

b. *Advantages.* The advantages of a preliminary demolitions are—

- Engineers normally complete each task and move to the next without having to leave demolition guards or firing parties at the site.
- Preparation efforts are less subject to interference by enemy or friendly troops.
- Elaborate precautions against failure are not required; preliminary demolitions require only single-firing systems.
- Engineers can perform the demolition operations for a particular target in stages rather than all at once.

c. *Progressive Preparation.* When preparation time is limited, engineers prepare the demolition in progressive stages. Doing this gives engineers the ability to create effective obstacles even if preparations must stop at any stage. For example, in the case of a bridge demolition, engineers would make one span the top priority, completely preparing it before continuing with other spans, piers, or abutments. As they complete other stages, engineers incorporate them into the firing system.

5-6. Reserved Demolitions.

a. *Purpose.* The responsible commander must carefully control a reserved demolition target because the target may be a vital part of the tactical or strategical plan or because the demolition will be performed in the face of the enemy.

b. *Considerations.* Occasionally, errors in orders, control, or timing cause serious consequences during demolition operations. In addition, engineers may encounter special problems when dealing with reserved demolition targets:

- Engineers must usually keep traffic lanes open until the last moment. This normally means they cannot use the simplest and quickest demolition techniques to accomplish the mission.

- The demolitions must be weatherproof and protected from traffic vibrations and enemy fire over long periods. Use dual firing systems, and carefully place and protect the demolitions from passing vehicles or pedestrians.
- A guard must remain at the demolition site until the demolitions are fired.

c. *States of Readiness.*

(1) State of Readiness 1 (Safe). The demolition charges are in place and secure. Vertical and horizontal ring mains are installed (Figure 2-33, page 2-27) but are not connected. Charges are primed with detonating-cord knots or wraps to minimize the time necessary to convert the system from State of Readiness 1 to State of Readiness 2. Charges that require blasting caps for priming cannot be primed at State of Readiness 1 nor can branch lines with caps crimped to them be connected to ring mains. Blasting caps and initiation sets are not attached to charges or firing systems.

(2) State of Readiness 2 (Armed). All vertical and horizontal ring mains are connected. Blasting caps are inappropriate charges and initiation sets are connected to ring mains. All charges and firing systems are complete and ready for detonation. The demolition is ready for immediate firing.

d. *Responsibilities.*

(1) Authorized Commanders. These commanders have overall responsibility for the operational plan. At any stage of the operation, they may delegate responsibilities. For example, when authorized commanders withdraw through other units' intermediate positions, they normally pass control to the commanders holding the intermediate positions. The commanders holding the intermediate positions then become the authorized commanders. Authorized comrnanders—

- Designate demolition targets as reserved targets.
- Order the demolition guard, detailing the strength and composition of the guard party.
- Specify the state of readiness and order changes to the state of readiness, if necessary.
- Give the orders to fire demolitions.
- May give the demolition guard or the firing-party commander the authority, in case of imminent capture, to fire the demolition on his own initiative.
- Destroy captured or abandoned explosives and demolition materials to prevent them from falling into enemy hands. Commanders should carefully select the demolition site and consider all safety precautions necessary when destroying abandoned demolitions. Chapter 6, Section IV (page 6-13), covers procedures and methods for destroying explosives.
- Issue the written instructions (demolition orders) to the unit providing the demolition guard and firing party.
- Notify all headquarters of any delegation of authority or reclassification of any demolition from a reserved to a preliminary status.
- Establish effective channels for communicating firing orders and readiness states to demolition guard commanders or firing-party commanders.

(2) Demolition Guard Commanders. These commanders are normally the infantry or armor task-force commanders who control the target area. These commanders—

- Command all troops and firing parties at reserved demolitions.
- Provide protection for reserved demolitions, firing parties, and targets.
- Control all traffic over or through targets.
- Pass written state-of-readiness orders to commanders of demolition firing parties, including changes to these orders.
- Keep authorized commanders informed of the status of preparations, targets, and operational situations at sites.
- Pass written firing orders to demolition firing-party commanders to fire demolitions.
- Report results of demolitions to authorized commanders.
- Maintain succession (chain of command) lists for appointment to demolition guard commander and demolition firing-party commander.

(3) Firing-Party Commanders. These commanders are normally officers or noncommissioned officers (NCOs) from the engineer unit that prepared the demolitions. They supervise the preparing, charging, and firing of the demolition. Firing-party commanders—

- Maintain the state of readiness specified by authorized commanders and advise demolition guard commanders of the time requirements for changing states of readiness and completing obstacles.
- Fire demolitions when ordered by the authorized commander, and ensure demolitions are successful and complete.
- Report the results of demolitions to demolition guard commanders or, if none, to the authorized commanders.
- Report the results of demolitions up the engineer chain of command and complete Section 5, pages 33 through 36, of the obstacle folder, if issued.
- Maintain succession (chain of command) lists for appointment as demolition firing-party commander should the initial commander become injured.

e. *Command and Control of Reserved Demolitions.*

(1) Command Post. Ideally, the demolition guard commander should place his command post where he can best control the defense of the demolition target from the friendly side. This location may conflict with the requirements of the demolition firing point, which should be close to or collocated with the command post. Usually, some compromise is necessary.

(2) Firing Point. The firing point is normally as close to the target as safety allows. The firing point must protect the firing party from the effects of blast and falling debris and be positioned so that the demolition firing-party commander is—

- Easily accessible to the demolition guard commander for receiving orders.
- In close contact with the firing party.
- Able to see the entire target.

(3) Alternate Positions. The demolition guard commander should designate an alternate command post and firing point, if possible. The firing party should be able to fire the demolitions from either the primary or alternate firing points.

(4) Check Point. When units are withdrawing from a enemy advance, identification can be a problem. Withdrawing troops are responsible for identifying themselves to the demolition guard. The demolition guard must always establish and operate a check point. The demolition guard commander may use military police to perform this duty. Good communication is essential between the check point and the demolition guard commander. Each unit withdrawing through the demolition target should send a liaison officer to the checkpoint, well in advance of the withdrawing unit's arrival.

(5) Refugee Control Points. The demolition guard commander may need to establish and operate a refugee control point for civilian traffic. He should place a check point on the enemy bank and a release point on the friendly bank to control refugees. The commander may use military or local police to operate the control points. The personnel operating the check points should halt refugees off the route and then escort them, in groups, across the target to the release point. Refugees must not interfere with the movement of withdrawing forces or demolition preparations.

Section III. Demolition Reconnaissance

5-7. Reconnaissance Orders. Thorough reconnaissance is necessary before planning a demolition operation. Reconnaissance provides detailed information in all areas related to the project. Prior to conducting any reconnaissance, the reconnaissance-party commander must receive clear objectives. The reconnaissance order specifies these objectives. This information helps the reconnaissance party to determine the best method of destroying the target and to estimate the preparation time required. For example, if the reconnaissance party knows that manpower and time are limited but explosives are plentiful, they may design demolitions requiring few men and little time but large quantities of explosives. These orders should detail the reconnaissance party to determine the following:

- Location and nature of the target.
- Purpose of the demolition operation (for example, to delay an enemy infantry battalion for three hours).
- Proposed classification of the demolition (reserved or preliminary).
- Type of firing system desired (dual or single).
- Economy of effort (whether the demolition must be completed in one stage or multiple stages).
- Utility of the target during demolition operations (whether the target must remain open to traffic during demolition preparations).
- Amount of time allowed or expected between preparation and execution of the demolition operation.
- Amount of time allowed for changing the state of readiness (Safe to Armed).
- Labor and equipment available for preparing the demolitions.

- Types and quantities of explosives available.

5-8. Reconnaissance Record. The reconnaissance party reports the results of their reconnaissance on DA Form 2203-R. Use the form with appropriate sketches, to record and report the reconnaissance of military demolition projects. Appendix F contains a sample of DA Form 2203-R (Figure F-2, pages F-38 through F-42) and instructions to complete it. For sketches, use available paper and attach to the completed DA Form 2203-R.

a. *Purpose.* When time and conditions permit, use this report as the source document for preparing the obstacle folder. If the obstacle folder is not available, use this report in its place. In certain instances the report may require a security classification.

b. *Information Required.* DA Form 2203-R should contain the following:

- A bill of explosives that shows the quantities and types required.
- A list of all equipment, including transportation, required for the demolition operation.
- An estimate of time and labor required for preparing the demolitions and placing the charges.
- A time and labor estimate for arming and firing the charges.
- A time, labor, and equipment estimate to complete any required bypass. Specify the bypass location and method. Include details for any supplementary obstacles required.
- A situation sketch showing the relative position of the target, terrain features, and coordinates of the target.
- A list of all unusual site characteristics. Indicate the location of these unusual characteristics on the situation sketch.
- Plan and elevation (side-view) sketches of the target, showing overall dimensions, lines of cut, and demolition chambers.
- Plan and elevation sketches of each member targeted, detailing dimensions, chambers, quantity of explosives, lines of cut, charge locations, and priming and initiation methods.
- A sketch showing firing circuits and firing points.

Section IV. Obstacle Folder

5-9. Purpose. The obstacle folder, as outlined in STANAG 2123 and QSTAG 743, provides all of the information necessary to complete a specific demolition operation. NATO and ABCA personnel use this booklet to collect information and to conduct demolition operations. The responsible commander should prepare an obstacle folder during peacetime for all preplanned targets to allow for efficient demolition operations. Prepare obstacle folders for reserved and preliminary demolitions. The obstacle folder is not normally used in tactical situations because the detailed information in the obstacle folder, including multiple languages, is not easily completed under field or tactical conditions. A sample obstacle folder is included in the sample target folder in Appendix F (page F-4).

5-10. Language. Since not all NATO and ABCA personnel speak the same language, obstacle folders must be multilingual. The preparing unit may speak a different language than the unit

actually conducting the demolition operation. Therefore, it is essential to prepare the obstacle folder in more than one language. However, prepare map notes, plans, sketches, and so forth, in one language, and provide translations for the other languages in the available space. Use the following guidelines when determining the languages necessary in an obstacle folder:

- Languages of the units involved in the demolitions.
- Language of the host nation.
- One of the two official NATO languages (English or French).

5-11. Contents. The obstacle folder contains six parts for recording information. Additional information may be noted in the appropriate place within the obstacle folder and then inserted as an additional page immediately following the notation (for example, "see page 4a"). The six parts of the obstacle folder are—

- Location of target (pages 1-5).
- Supply of explosives and equipment (pages 6-17).
- Orders for preparing and firing (pages 18-28).
- Hand-over and take-over instructions (pages 29-32).
- Demolition report (pages 33-37).
- Official signature (page 38).

5-12. Special Instructions. The list of explosives, stores, and mines required (paragraph 2d, pages 14 and 16 of the obstacle folder) does not cover every possible situation. However, it does indicate a logical order for recording or determining the required materials. Mark only the materials required for your particular target. The transport team leader uses the first list. For major operations, note the size, composition, and mission of the various work parties participating in paragraph 3a, subparagraph 5. Paragraph 3a, subparagraph 6 concerns only nuisance or protective mine fields laid to protect the demolition target and does not apply to tactical (barrier) mine fields. Complete paragraph 5 of the Demolition Report upon completion of the demolition. The firing party commander may detach the first copy of the demolition report (pages 33-37) and forward it to a higher-echelon engineer headquarters.

Chapter 6
Demolition Safety

Section I. General Safety

6-1. Considerations.

- Do *not* attempt to conduct a demolitions mission if you are unsure of demolition procedures; review references or obtain assistance.
- Prevent inexperienced personnel from handling explosives.
- Avoid dividing responsibility for demolition operations.
- Use the minimum number of personnel necessary to accomplish the demolitions mission.
- Take your time when working with explosives; make your actions deliberate.
- Always post guards to prevent access inside the danger radius.
- Always maintain control of the blasting machine or initiation source.
- Use the minimum amount of explosives necessary to accomplish the mission while keeping sufficient explosives in reserve to handle any possible misfires.
- Maintain accurate accountability of all explosives and accessories. Always store blasting caps separately and at a safe distance from other explosives.
- Ensure all personnel and equipment are accounted for prior to detonating a charge.
- Ensure you give warnings before initiating demolitions; give the warning "Free in the hole!" three times.
- Always guard firing points.
- Assign a competent safety officer for every demolition mission.
- Dual initiate all demolitions, regardless of whether they are single-or dual-primed.
- Avoid using deteriorated or damaged explosives.
- Do not dismantle or alter the contents of any explosive material.
- Avoid mixing live and inert (dummy) explosives.

WARNING
Do not use blasting caps underground.
Use detonating cord to prime underground charges.

6-2. Explosive Materials.

a. *Blasting Caps.* Both military and commercial blasting caps are extremely sensitive and can explode unless handled carefully. Blasting caps can detonate if exposed to extreme heat *(cook off).* Military blasting caps are more powerful and often more sensitive than their commercial counterparts. When using commercial blasting caps to detonate military explosives, ensure they are powerful enough to detonate the explosives, thus, avoiding misfires. Because power

requirements for caps from different manufacturers vary, never mix caps from different manufacturers; mixing caps could result in rnisfires. When installing caps in explosives, never force them into an explosive or a cap well; use an appropriate tool for making or enlarging the cap well. Ensure 1/8 to 1/4 inch of the cap is clearly visible at both ends when taping onto detonation cord. Do not connect blasting-cap initiation sets to ring or line mains or charges when nonessential personnel are on site. Never leave blasting caps unattended before or after attaching them to the charges or firing system.

(1) Nonelectric.

- Use only authorized equipment and procedures when crimping nonelectric blasting caps to time fuse or detonating cord.
- Maintain blasting caps in the appropriate cap box until needed. Never store blasting caps with explosives.
- Never carry loose blasting caps in your pocket or place loose blasting caps in a container; secure them.
- Do not blow into a nonelectric cap or attempt to remove any obstructions from the blasting cap well. Remove obstructions that will dislodge by using the wrist-to-wrist tap method.
- Never insert anything but time fuse or detonation cord into a nonelectric blasting cap. Do not twist time fuse or detonating cord while attempting to insert into a blasting cap.
- Never attempt to crimp a blasting cap installed in an explosive. If the blasting cap has come loose from the time fuse or detonating cord, remove the blasting cap from the charge, recrimp the cap, and then reinstall the cap in the charge.
- Avoid striking, pinching, and mashing nonelectric caps during crimping activities. Use only the M2 crimpers for all crimping operations.
- When using nonelectric caps to dual prime demolitions, cut the fuse to allow an interval of not less than 10 seconds between firings.

(2) Electric.

- Do not remove the short-circuiting shunt unless testing or connecting the cap. The shunt prevents accidental initiation by static electricity. If the blasting cap has no shunt, twist the bare ends of the lead wires together at least three times (180-degree turns) to provide a proper shunt.
- Use proper grounding procedures when static electricity is present, see paragraph 6-5b (page 6-4).
- When transporting electric blasting caps near vehicles (including aircraft) equipped with a transmitter, protect the blasting caps by placing them in a metal can with a snug-fitting cover (½ inch or more of cover overlap). Do not remove blasting caps from their containers near an operating transmitter unless the hazard has been judged acceptable.
- Keep electric blasting caps at least 155 meters from energized power lines. If using electric blasting caps near power lines, temporarily cut the power to the lines during blasting operations.
- Always use at least the minimum current required to fire electric blasting caps.

- Always check circuit continuity of electric blasting caps before use.
- Cover connections between blasting cap leads and firing wires with insulating tape, not the cardboard spool.
- Remove firing wire loops and, if practical, bury blasting wires.

b. *Time Fuse and Detonating Cord.*

(1) Time Fuse.

- Always conduct a test burn of at least three feet for each roll of time fuse. If you do not use the fuse within 24 hours of the test burn, perform another test burn before using the fuse.
- Use M2 crimpers to cut time fuse. If serviceable M2 crimpers are not available, use a sharp knife to cut fuse. Be sure to cut the fuse end squarely. Make the cut on a nonsparking surface, such as wood. A rough or jagged-cut fuse can cause a misfire.
- Avoid cutting the fuse until you are ready to insert it into the igniter and blasting cap.
- To avoid problems from moisture infiltration, never use the first or last 6 inches of time fuse from a new or partial roll.
- Avoid sharp bends, loops, and kinks in time fuse. Avoid stepping on the fuse. Any of these conditions or actions can break the powder train and result in a misfire.

(2) Detonating Cord.

- Do not carry or hold detonating cord by placing it around your neck.
- To avoid problems from moisture infiltration, never use the first or last 6 inches of detonating cord from anew or partial roll.
- Avoid sharp bends, loops, and kinks in detonating cord. Avoid stepping on the cord. Any of these conditions or actions can change the path of detonation or cause the cord to cut itself.

c. *Plastic and Sheet Explosives.*

- Always cut plastic and sheet explosives with a sharp knife on a nonsparking surface. Never use shears.
- Avoid handling explosives with your bare skin as much as possible.

d. *Picric Acid.* Picric acid degrades with time. Do not use picric acid if its container is rusted or corroded. A rusty or corroded container indicates the explosive is unstable.

WARNING
Do not handle picric acid. Notify EOD for disposition.

e. *Commercial Explosives.* Commercial dynamite is sensitive to shock and friction and is not recommended for use in combat areas. Do not use old, commercial dynamite because it is extremely sensitive and very unstable. Follow the procedures in TM 9-1300-206 or the manufacturer's recommendations to destroy aged commercial dynamite. When commercial dynamite freezes, it becomes covered with crystals and is very unstable. Do not use frozen dynamite. Commercial

dynamite containing nitroglycerin requires special handling and storage. Rotate commercial dynamite in storage to prevent the nitroglycerin from settling to the bottom of the explosive.

6-3. Boreholes. Do not leave any void spaces in boreholes, especially in quarrying operations. A secondary explosion can result from a borehole with voids between loaded explosives. After the first blast, it may take up to 15 minutes for such an explosion to occur. Tamp all voids with appropriate material. When using springing charges to dig boreholes, allow at least 2 hours for boreholes to cool between placing and firing successive springing charges, or cool the boreholes with water or compressed air to save time.

6-4. Toxicity. Most military explosives are poisonous if ingested and will produce lethal gases if detonated in confined areas such as tunnels, caves, bunkers, and buildings. Allow sufficient time for blast fumes, dust, and mists to clear before inspecting or occupying a blasting area. TNT is extremely poisonous; avoid using TNT to blast in enclosed areas. Avoid touching sensitive areas of your body, such as around the face and groin, when working with explosives. Wash your hands after working with explosives, especially before consuming food.

6-5. Natural and Physical Properties.

a. *Lightning.* Lightning is a hazard to both electric and nonelectric blasting charges. A lightning strike or nearby miss is almost certain to initiate either type of system. If lightning strikes occur, even far away from the blasting site, electrical firing circuits could be initiated by high, local earth currents and shock waves resulting from the strikes. These effects are increased when lightning strikes occur near conducting elements, such as fences, railroads, bridges, streams, underground cables or conduits, and in or near buildings. The only safe procedure is to suspend all blasting activities during electrical storms or when an electrical storm is imminent.

b. *Static Electricity.* Though rare, electric blasting caps can possibly be initiated by static electricity. If possible, avoid using electric blasting caps if static electricity is a problem. Exercise extreme caution when working with explosives in cold, dry climates or when wearing clothing and equipment that produce static electricity, such as clothing made of nylon or wool. Before handling an electric blasting cap, always remove the static electricity from your body by touching the earth or a grounded object. It may be necessary to perform this grounding procedure often in an area where static electricity is a constant problem.

c. Induced Currents. Radio signals can induce a current in electric blasting caps and prematurely detonate them. Table 6-1 lists the minimum safe distances from transmitters for safe electrical blasting. This table applies to operating radio, radar, microwave, and television transmitting equipment. Keep mobile transmitters and portable transmitters at least 50 meters from any electric blasting cap or electrical firing system. Do not use electric blasting caps within 155 meters of energized power transmission lines.

d. *Blast Effects.* Personnel in close proximity to explosions may experience permanent hearing loss or other injury from the pressure wave caused by an explosion. Hearing protection should be worn during all blasting operations. Personnel observing minimum safe distances for bare charges (see Table 6-1 and Army Regulation (AR) 385-63) generally will not be affected by blast effects. Refer to AR 385-63, Chapter 18, for additional information on blast effect.

Table 6-1. Safe distances for blasting near radio frequency energy

Average or Peak Transmitter Power (Watts*)	Minimum Safe Distance (Meters)
0 to 29	30
30 to 49	50
50 to 99	110
100 to 249	160
250 to 499	230
500 to 999	305
1,000 to 2,999	480
3,000 to 4,999	610
5,000 to 19,999	915
20,000 to 49,999	1,530
50,000 to 100,000	3,050
*When the transmission is a pulsed- or pulsed, continuous-wave type and its pulse width are less than 10 microseconds, the left-hand column indicates average power. For all other transmitters, including those with pulse widths greater than 10 microseconds, the left-hand column indicates peak power.	

e. *Missile Hazards.* Explosives can propel lethal missiles great distances. The distances these missiles will travel in air depend primarily on the relationship between the missiles' weight, shape, density, initial angle of projection, and initial speed. Under normal conditions, the missile-hazard area of steel-cutting charges is greater than that of cratering, quarrying, and surface charges.

6-6. Underwater Operations.

a. *Explosives.* Explosives are subject to erosion by water. Unprotected explosives will deteriorate rapidly, reducing their effectiveness. Ensure all exposed explosives are adequately protected when used in water, especially running water.

b. *Nonelectric Caps.* Nonelectric caps depend on combustion to work properly. Any moisture inside a nonelectric cap may cause a misfire. Because nonelectric blasting caps are difficult to waterproof, aviod using them to prime underwater charges or charges placed in wet boreholes.

c. *Time Fuse.* Time fuse depends on combustion to burn properly. Time fuse burns significantly faster underwater due to water pressure. Waterproof sealing compounds will not make a permanent waterproof seal between the fuse and a nonelectric blasting cap. Place the fuse underwater at the last possible moment before firing.

NOTE: If the mission requires using time fuse underwater, then do the test burn underwater.

d. *Detonating Cord.* Seal the ends of detonating cord with a waterproof sealing compound when using detonating cord for initiating underwater charges or charges that will remain in place

several hours before firing. Leaving a 6-inch overhang in detonating cord normally will protect the remaining line from moisture for 24 hours.

e. *M60 Fuze Igniter.* The M60 depends on combustion to work properly. Water can penetrate the fuze igniter through the vent hole located in the pull rod. Therefore, if the igniter fails to fire on the initial attempt, it probably will fail on any subsequent attempt after reset. Always use a backup initiation set for underwater demolitions.

6-7. Safe Distances. The following criteria give distances at which personnel in the open are relatively safe from missiles created by bare charges placed on the ground, regardless of the type or condition of the soil (AR 385-63). Table 6-2 lists safe distances for selected charge weights. The following general rules apply:

- Charges of Less Than 27 Pounds. The minimum missile hazard distance is 300 meters.
- Charges of More Than 27 Pounds But Less Than 500 Pounds. Use the distances in Table 6-2.
- Charges More Than 500 Pounds. Use the following formulas:

$$\textit{Safe Distance (meters)} = 100\sqrt[3]{\textit{Pounds of Explosive}} \qquad (6\text{-}1)$$

$$\textit{Safe Distance (feet)} = 300\sqrt[3]{\textit{Pounds of Explosive}} \qquad (6\text{-}2)$$

- Missile-Proof Shelters. A missile-proof shelter can be as close as 100 meters from the detonation site provided it is strong enough to withstand the heaviest possible missile resulting from the demolition.
- Charges Fixed to Targets. When charges are fixed to targets and not simply placed on the ground, use the safe distances specified in Tables 6-2 or 6-3, whichever is farthest. Note that these distances depend on the target configuration, not quantity of explosive.

Table 6-2. Safe distances for personnel (near bare charges)

Explosive Weight (Pounds)	Safe Distance		Explosive Weight (Pounds)	Safe Distance	
	Feet	Meters		Feet	Meters
27 or less	985	300	175	1,838	560
30	1,021	311	200	1,920	585
35	1,073	327	225	1,999	609
40	1,123	342	250	2.067	630
45	1,168	356	275	2,136	651
50	1,211	369	300	2,199	670
60	1,287	392	325	2,258	688
70	1,355	413	350	2,313	705
80	1,415	431	375	2,369	722
90	1,474	449	400	2,418	737
100	1,526	465	425	2,461	750
125	1,641	500	500	2,625	800
150	1,752	534			

Table 6-3. Safe distances for personnel (charges on target)

Serial	Charge Type	Target	Charge Size	Radius of Danger Area (m)	Remarks
a	b	c	d	e	f
1	Blasting caps Primers Detonating cord (in the open)	—	—	20	For service personnel under supervision. Applicable to all serials.
2	Cutting	a. Trees	Any	300	
		b. Concrete columns and beams	Any	500	—
		c. Metal girders and plates, guns, and so forth	Any	1,000	Fragments may fly up to 1,000 meters in all directions.
3	Concussion	Buildings and AFV	Any	1,000	If personnel are wearing helmets, you may reduce the safe distance to 500 meters. Consider the strong blast effect when considering buildings as potential blast shelters.
4	Cratering	Roads and airfields	a.. Up to 2 kg	100	
			b. Up to 30 kg	300	
			c. Over 30 kg	500	
5	Mines	Piers Abutments Retaining walls	Any	500	
6	Borehole	Rock Masonry Concrete Brick	Any	300	
7	Breaching	Reinforced-concrete beams and slabs Mass-concrete walls and obstacles	Any	1,000	If personnel are wearing helmets, you may reduce the safe distance to 500 meters. Consider the strong blast effect when considering buildings as potential blast shelters.
8	Shaped	Concrete Steel	Any	1,000	When these charges are fired into the ground vertically, you may reduce the safe distance to 300 meters.
9	Bangalore Torpedo	Wire obstacles	—	a. All right angles to axis, 1,000 meters	
			—	b. In the line of the axis, 200 meters for standing personnel and 100 meters for prone personnel	
10	M180	Roads and airfields	1-15 kits	1,200	Fragments may fly up to 1,000 meters in all directions.

NOTES:

1. The air clearance required is the ground safety distance plus 500 meters above the explosive area.
2. The ship clearance required is the same distance as for the ground safety distance.

Section II. Misfire Procedures

6-8. Nonelectric Misfires.

a. *Causes.*

- Moisture in the time fuse, detonating cord, or explosives.
- Time fuse not seated completely in blasting cap or in fuse igniter.
- Breaks in time fuse or detonating cord.
- Jagged or uneven ends on time fuse.
- Blasting caps not seated securely in cap well or explosive.
- Loose or improper detonating-cord installation.
- Debris in the blasting cap.
- Commercial blasting caps were not strong enough to detonate military explosives.

b. *Prevention.* You can minimize nonelectric misfires by taking the following precautions:

- Prepare and place all primers properly.
- Load all charges carefully.
- Detonate charges with the proper techniques.
- Use dual-initiation systems and, if possible, dual firing systems.
- Use detonating cord for underground demolitions. *Do not bury caps!*
- Perform tamping operations with care to avoid damaging prepared charges.
- Avoid crimping blasting caps onto time fuse in the rain; seek a covered area out of the rain.
- Ensure you completely seat time fuse when installing it into a blasting cap or fuse igniter.

c. *Clearing Procedure.*

- The soldier who placed the charges should investigate and correct any problems with the demolition.
- After attempting to fire the demolition, delay investigating any detonation problem for at least 30 minutes plus the time remaining on the secondary. Tactical conditions may require investigation prior to the 30-minute limit.
- For above-ground misfires of charges primed with blasting caps, place a primed, l-pound charge next to the misfired charge and detonate the new charge. Each misfired charge or charge separated from the firing circuit that contains a blasting cap requires a 1-pound charge for detonation. Do not touch scattered charges that contain blasting caps; destroy therein place. For charges primed with detonating cord, use the procedures in paragraph 6-10 (page 6-10).
- For a nonelectric cap that has detonated but failed to initiate a detonating-cord branch line, line main, or ring main, attach a new cap to the detonating cord, and then move to a safe place.

- For buried charges, remove the tamping to within one foot of the misfired charge. Constantly check depth while digging to avoid striking the charge. When within 1 foot of the misfired charge, place a primed, 2-pound charge on top of the original charge and detonate the new charge. If digging over the original charge is impractical, dig a new borehole of the same depth beside the original hole, l-foot away. Place a primed, 2-pound charge in the new hole and detonate the new charge.

6-9. Electric Misfires.

a. *Causes.*

- Inoperable or weak blasting machine or power source.
- Improper operation of blasting machine or power source.
- Defective or damaged connections. (Short circuits, breaks in the circuit, or too much resistance in the electrical wiring are common conditions resulting in misfires.)
- Faulty blasting caps.
- Blasting caps made by different manufacturers in the same circuit.
- Power source inadequate for the number of blasting caps in the circuit (too many caps, too small a blasting machine).

b. *Prevention.* Assign one individual the responsibility for all the electrical wiring in a demolition circuit. This individual should do the following:

- Perform all splicing.
- Install all blasting caps in the firing circuit. *Do not bury caps!*
- Make all of the connections between blasting cap wires, connecting wires, and firing wires.
- Inspect system for short circuits.
- Avoid grounding out the system.
- Ensure the number of blasting caps in any circuit does not exceed the rated capacity of the power source.

c. *Clearing Procedure.* Use the following procedures to clear electric misfires:

- Make another attempt to fire.
- Use the secondary firing system, when present.
- Check the wire connections, blasting machine, or power-source terminals.
- Disconnect the blasting machine or power source and test the blasting circuit. Check the continuity of the firing wire with a circuit tester.
- Use another blasting machine or power source and attempt to fire the demolition again, or change operators.
- When employing *only one* electrical initiation system, disconnect the blasting machine, shunt the wires, and investigate immediately. When employing *more than one* electrical initiation system, wait 30 minutes before inspecting. Tactical conditions may require investigation prior to the 30-minute limit.

- Inspect the entire circuit for wire breaks or short circuits.
- If you suspect an electric blasting cap is the problem, do not attempt to remove or handle it. Place a primed, 1-pound charge next to the misfired charge and detonate the new charge.

6-10. Detonating-Cord Misfires.

a. *Detonating Cord.* If detonating cord fails to function properly, take the following action:

- Attach a new blasting cap to the remaining detonating cord, taking care to fasten it properly, and detonate the new blasting cap.
- Treat branch lines in the same manner as noted above.

b. *Detonating-Cord Priming.* If the detonating cord leading to the charge detonates but fails to explode the charge, take the following action:

- Do not investigate until the charges have stopped burning. Wait 30 minutes if the charge is underground.
- Reprime and attempt to detonate the charge.
- Scattered charges that do not contain blasting caps may be collected and detonated together.
- For underground charges, dig to within one foot of the charge; place a primed, 2-pound charge on top or to the side of the charge; and detonate the new charge.

Section III. Transportation and Storage Safety

6-11. Transportation.

a. *Regulations.* Both military and commercial carriers are subject to regulations when transporting military explosives and other dangerous military materials within the United States. AR 55-355 covers the transportation of explosives. When transporting explosives outside the United States, follow the regulations from the host countries as well. TM 9-1300-206 contains minimum safety requirements for handling and transporting military explosives and ammunition. All explosives transport personnel must learn the local procedures and safety requirements.

b. *Safety Procedures. The* commander should assign a primary and assistant operator to each vehicle transporting explosives on public highways, roads, or streets. Whenever transporting explosives locally, operators must observe the following safety rules:

(1) Vehicles.

- Ensure vehicles are in good condition. Inspect all vehicles intended for hauling explosives before loading any explosives. Pay particular attention to protecting against any short circuits in the electrical system.
- When using vehicles with steel or partial-steel bodies, install fire-resistant and nonsparking cushioning to separate the explosives from the metal truck components.
- Do not load vehicles beyond their rated capacities when transporting explosives.

- Cover open-body vehicles hauling explosives with a fire-resistant tarpaulin.
- Mark all vehicles transporting explosives with reflective placards indicating the type of explosives carried (TM 9-1300-206, Chapter 6).
- Use demolition transports for explosives only. Do not carry metal tools, carbides, oils, matches, firearms, electric storage batteries, flammable substances, acids, or oxidizing or corrosive compounds in the bed or body of any vehicle transporting explosives.
- Equip vehicles transporting explosives with not less than two Class 1-BC fire extinguishers for on-post shipments. Place the extinguishers at strategic points, ready for immediate use.
- Keep vehicles away from congested areas. Consider congestion when parking.
- Operate vehicles transporting explosives with extreme cam. Do not drive at a speed greater than 35 miles per hour. Make full stops at approaches to all railroad crossings and main highways. This does not apply to convoys or crossings protected by guards or highway workers (flaggers).
- Keep flames at least 50 feet from vehicles or storage points containing explosives.

(2) Cargo (Explosives).

- Never leave explosives unattended.
- Never mix live and inert (dummy) explosives.
- Secure the load of explosives in the transport to prevent shifting during transport.
- Transport blasting caps separately from other explosives. Do not transport blasting caps or other initiators in the same vehicles carrying explosives. If both blasting caps and explosives must be carried in the same vehicle, separate blasting caps from the other explosives by carrying the caps in a closed metal container in the cab of the transport.
- No persons other than the primary and the assistant operators will ride on or in a truck transporting explosives. Do not refuel a vehicle while carrying explosives except in an emergency.

(3) Fire. If fire breaks out in a vehicle transporting explosives, take the following actions:

- Try to stop the vehicle away from any populated areas.
- Stop traffic from both directions. Warn vehicle drivers and passengers and occupants of nearby buildings to keep at least 2,000 feet away from the fire.
- Inform police, fire fighters, and other emergency-response personnel that the cargo is explosives.
- If the fire involves only the engine, cab, chassis, or tires, make an effort to extinguish the fire with fire extinguishers, sand, dirt, or water. If the fire spreads to the body of the transport or the cargo, stop fighting the fire and evacuate to a distance of at least 2,000 feet.
- Do not attempt to extinguish burning explosives without expert advice and assistance.

6-12. Storage Safety.

a. *Magazines.* There are two types of magazines: permanent and temporary. Although permanent magazines are preferred, temporary or emergency magazines are frequently required when permanent construction is not possible. Field Manual (FM) 9-6 and TM 9-1300-206 give details on magazine storage of explosives. Consider the following when constructing magazines:

(1) Permanent.

(a) Placement. Consider acceptability of magazine locations based on safety requirements, accessibility, dryness, and drainage. Safety and accessibility are the most important. An ideal location is a hilly area where the height of the ground above the magazine provides a natural wall or barrier to buildings, centers of communication, and other magazines in the area. Hillside bunkers are not desirable because adequate ventilation and drainage are often difficult to achieve. Clear brush and tall grass from the site to lessen the danger of fire.

(b) Lightning protection. All magazines must have a grounded, overhead lightning-rod system. Connect all metal parts (doors, ventilator, window sashes, reinforcing steel, and so forth) to buried conduits of copperplate or graphite rods in several places.

(c) Barricades. Install barricades around magazines; that is, there must be a substantial obstacle between magazines and inhabited buildings. For certain explosives, effective natural or artificial barricades reduce the required safe distance between magazines and railways and highways by one half. The use of barricades permits the storage of larger quantities of explosives in any given area. Although barricades help protect magazines against explosives and bomb or shell fragments, they do not safeguard against pressure damage. TM 9-1300-206 gives more specific guidance on barricades.

(d) Security. Place guards at all magazines to prevent unauthorized personnel from gaining access to magazine facilities.

(2) Temporary.

(a) Placement. When permanent magazine construction is not possible, create temporary magazines by placing explosives on pallets to accommodate ventilation. Store the pallets in a well-drained bunker. Excavate the bunker in a dry area and revet the bunker with timber to prevent collapse. Alternatives are an isolated building or a light, wooden-frame house with a wedge-type roof covered with corrugated iron or tent canvas.

(b) Identification. Mark field-expedient storage facilities on all four sides with signs (TM 9-1300-206).

b. *Temporary Storage.* When necessary, store limited supplies of explosives in covered ammunition shelters. Ensure the temporary facilities are separated adequately to prevent fire or explosion from being transmitted between shelters. Piles of temporarily stored explosives should contain no more than 500 pounds each and be spaced no closer than 140 feet. Pile explosive components separately. Keep explosives, caps, and other demolition materials stored in training areas in covered ammunition shelters and under guard at all times. Local safety standing operating procedures (SOPS) and TM 9-1300-206, Chapter 4, are guides for temporary storage operations.

Section IV. Destruction of Military Explosives

6-13. Concept. Destruction of demolition materials is a unit commander's decision. The purpose of this intentional destruction is to prevent the enemy from capturing stockpiles of explosives. Whenever the commander orders destruction, two primary considerations are site selection and safety precautions. EOD units are responsible for destroying damaged or unserviceable explosives and demolition materials (AR 75-14, TM 43-0001-38, and FM 9- 16). Completely destroy explosive and nonexplosive demolition materials in a combat zone. Damage essential components of sets and kits to prevent complete assembly by cannibalizing from undamaged components. Such destruction is a command decision based on the tactical situation, security classification of the demolition materials, their quantity and location, facilities for accomplishing destruction, and time available. In general, burning and detonating or a combination of both are the most effective means of destruction.

6-14. Site Selection. Select the site for its ability to provide the greatest obstruction to enemy movement but prevent hazards to friendly troops. Even in the fastest-paced operations, safety is important, and you should adhere to appropriate safety precautions, if possible.

6-15. Methods. Burning and detonating, in that order, are considered the most satisfactory methods for destroying demolition materials to prevent enemy use. TM 9-1300-206 (Chapter 9) and TM 9-1300-214 (Chapter 15) cover procedures for explosives and ammunition destruction in greater detail.

a. *Burning.* Destroy packed and unpacked high-explosive items by burning. These explosives include linear demolition charges, shaped demolition charges, block demolition charges, stick dynamite, detonating cord, firing devices, timed blasting fuse, and similar items. Do not attempt to destroy blasting caps by burning them since they will detonate from extreme heat. Separate them from other explosives and destroy them by detonation. Personnel should not attempt to extinguish burning explosives without expert advice and assistance. Use the following procedure for burning explosives:

- Place blasting caps in piles separate from explosives and destroy by detonation. Ensure blasting caps are stored far enough away from the other explosives being burned to prevent the burning explosives from detonating the blasting caps or vice versa.
- Stack explosives in a pile over a layer of combustible material. Piles should not exceed 2,000 pounds or be more than 3 inches thick.
- Ignite the pile with a combustible train (excelsior or slow-burning propellant) of suitable length, and take cover immediately. Calculate the safe distance from the pile using Table 6-1 (page 6-5). This distance is never less than 300 meters.
- Do not try to extinguish burning explosives. Burning explosives cannot be extinguished by smothering them or drenching them. In fact, smothering will probably cause an explosion. Personnel should not attempt to extinguish burning explosives without expert advice and assistance.

b. *Detonation.* The tactical situation, the commander's intent, the lack of time, the type of explosive, or the safety considerations may require an explosive to be detonated instead of burned. Use the following procedures for detonating explosives:

- Establish a safety zone for missile and blast effect by computing the safe distance required for the amount of explosives to be detonated (Table 6-1, page 6-5).
- Do not exceed the limitations of the disposal site, Instead of detonating one large pile of explosives, it may be necessary to make several smaller piles of explosives and stagger their detonating times.
- Use a minimum of two initiation systems to detonate a pile of explosives.
- Prime explosives every 4 to 5 feet when placing explosives in long rows or lines.
- Ensure positive contact between primed charges and other explosives in the pile or row.

Appendix A
Example Calculations

A-1. Application. This appendix contains examples of charge, demolition, and attack calculations. Users should be familiar with the discussions in Chapters 3 and 4. Use TNT in the l-pound package and C4 in the 1.25-pound package when calculating the following problems. The volume of a package of C4 is 20 cubic inches.

A-2. Charge Calculations.

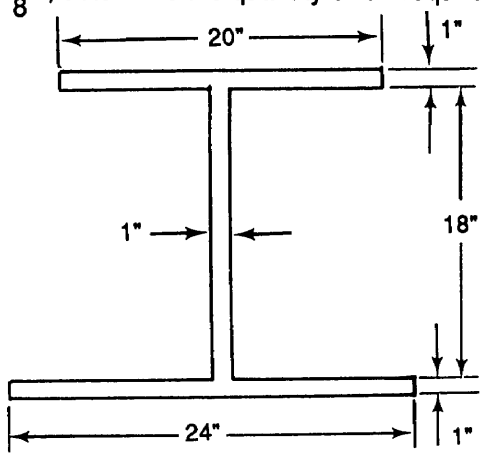
Problem: Determine the quantity of C4 required to cut a 30-inch diameter tree, using an internal timber charge.	
Step 1	Obtain critical dimensions: $D = 30$ inches.
Step 2	Calculate for TNT/Rule of Thumb: $P = \frac{D^2}{250} = \frac{30^2}{250} = \frac{900}{250} =$ 3.6 *pounds of TNT*
Step 3	Divide by the RE factor, if required: $\frac{P}{RE} = \frac{3.6}{1.34} = 2.68$ *pounds of C4*
Step 4	Divide by package weight/volume and round UP to next whole package: $\frac{P}{1.25} = \frac{2.68}{1.25} = 2.14$ *packages of C4*, round up to 3 packages of C4.
Step 5	Calculate number of charges: *One Tree = One Charge*
NOTE: You must split the charge between two boreholes because the tree is larger than 18 inches in diameter. See paragraph 3-5a (page 3-4).	
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 3 x 1 = 3 packages of C4*
Solution: Three packages of C4, placed in two boreholes, are required to cut a 30-inch diameter tree, using an internal timber charge. For placement of charge, see Figure 3-2 (page 3-5).	

Example A-1. Timber-cutting charge calculation (internal)

Problem: Determine the quantity of TNT required to cut a 30-inch diameter tree using an external timber charge.	
Step 1	Obtain critical dimensions: *D = 30 inches*
Step 2	Calculate for TNT/Rule of Thumb: $P = \frac{D^2}{40} = \frac{30^2}{40} = \frac{900}{40} = 22.5$ *pounds of TNT*
Step 3	Divide by RE factor, if required: $\frac{P}{RE} = \frac{22.5}{1} = 22.5$ *pounds of TNT*
Step 4	Divide by package weight/volume and round UP to next whole package: $\frac{P}{1} = \frac{22.5}{1} = 22.5$ Round up to 23 packages of TNT.
Step 5	Calculate number of charges: *One Tree = One Charge*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 23 x 1 = 23 packages of TNT*
Solution: 23 packages of TNT are required to cut a 30-inch diameter tree, using an external timber charge. For placement of charge, see Figure 3-3 (page 3-5).	

Example A-2. Timber-cutting charge calculation (external)

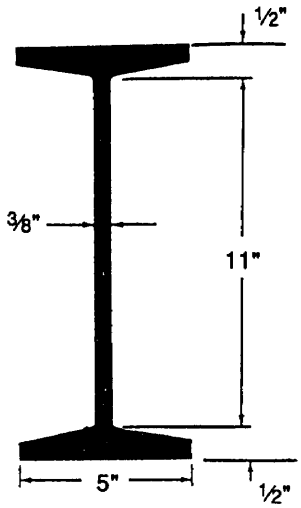
Problem: Using the formula $P = \frac{3}{8}A$, determine the quantity of C4 required to cut the two steel beams shown below.



Step 1	Obtain critical dimensions: a. Top Flange: 20 x 1 = 20 square inches b. Web: 18 x 1 = 18 square inches c. Bottom Flange: 24 x 1 = 24 square inches
Step 2	Calculate for TNT/Rule of Thumb: a. Top Flange: 20 x 1 = 20 square inches b. Web: 18 x 1 = 18 square inches c. Bottom Flange: 24 x 1 = 24 square inches d. Total Square Inches = 62 square inches $P = \frac{3}{8}A = \frac{3}{8} \times 62 = 23.25$ *pounds of TNT*
Step 3	Divide by RE factor, if required: $\frac{23.25}{1.34} = 17.35$ *pounds of C4*
Step 4	Divide by package weight/volume and round UP to next whole package: $\frac{17.35}{1.25} = 13.88$ Round up to 14 packages of C4.
Step 5	Calculate number of charges: *Two Beams = Two Charges*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 14 x 2 = 28 packages of C4*
Solution: 28 packages of C4 are required to cut the two beams. For placement of charge, see Figure 3-7 (page 3-9).	

Example A-3. Steel-cutting charge calculation

Problem: Using Table 3-3 (page 3-10), determine the quantity of C4 required to cut the steel beam shown below.



$P = 3/8\ A$

Area of flange = 2 x 1/2 x 5 = 5 square inches

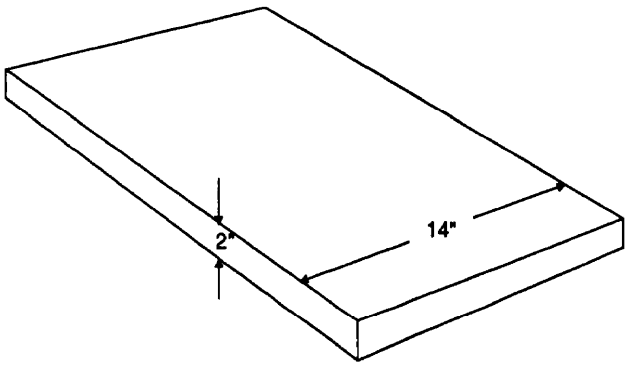
Area of Web = 3/8 x 11 = 4 1/8 square inches

Total area (A) = 9 1/8 square inches

Step 1	Otain the critical dimensions: a. Top Flange: 5 x 1/2 inches b. Web: 11 x 3/8 inches c. Bottom Flange: 5 x 1/2 inches
Step 2	Calculate for TNT/Rule of Thumb: a. Top Flange: 5 x 1/2 = 0.8 pounds from Table 3-3 b. Web: 11 x 3/8 = 1.3 pounds from Table 3-3 c. Bottom Flange: 5 x 1/2 = 0.8 pounds from Table 3-3 d. Total: = 2.9 pounds of C4
Step 3	Divide by RE factor, if required: Not required
Step 4	Divide by package weight/volume and round UP to next whole package: $\frac{P}{\textit{Package Weight}} = \frac{2.9\ \textit{Pounds of C4}}{1.25\ \textit{Package Weight}} = 2.32$ Round up to 3 packages of C4.
Step 5	Calculate number of charges: *One Beam = One Charge*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 3 x 1 = 3 packages of C4*
Solution: Three packages of C4 are required. For placement of charge, see Figure 3-7 (page 3-9).	

Example A-4. Hasty steel-cutting charge calculation

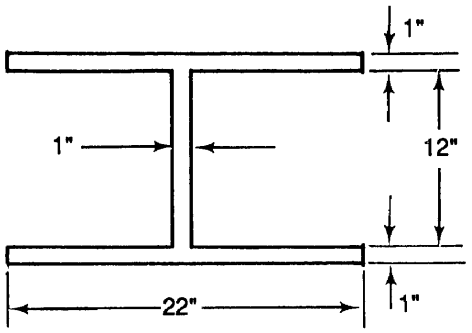
Problem: Using ribbon charge, determine the quantity of C4 required to cut the steel plate shown below.

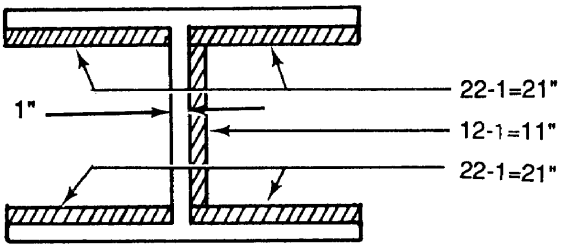


Step 1	Obtain the critical dimensions: a. Cut Length: 14 inches b. Target Thickness: 2 inches
Step 2	Calculate for TNT/Rule of Thumb: a. Thickness: 1/2(Target Thickness) = 1 inch b. Width: 3(Charge Thickness) = 3 inches c. Length: Cut Length = 14 inches *Volume = T x W x L = 1 x 3 x 14 = 42 cubic inches*
Step 3	Divide by RE factor, if required: Not required because only C4 or sheet explosives are used.
Step 4	Divide by package weight/volume and round UP to next whole package: $N = \frac{Charge\ Volume}{Package\ Volume} = \frac{42}{20} = 2.1$ Round up to 3 packages of C4.
Step 5	Calculate number of charges: *One Plate = One Charge*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 3 x 1 = 3 packages*
Solution: Three packages of C4 are required to cut the steel plate. For placement of charge, see Figure 3-11 (page 3-13).	

Example A-5. Steel-cutting charge calculation (steel plate)

Problem: Using ribbon charge, determine the quantity of C4 required to cut the I-beam shown below.



Step 1	Obtain critical dimensions: a. Top Flange: 22 x 1 = 22 inches b. Web: 12 x 1 = 12 inches c. Bottom Flange: 22 x 1 = 22 inches
Step 2	Calculate for TNT/Rule of Thumb: a. Thickness = 1/2(Target Thickness) = 1/2 inches b. Width = 3(Charge Thickness) = 1 1/2 inches c. Length = Cut Length = 21 + 21 + 11 = 53 inches *Volume = T x W x L = 1/2 x 1 1/2 x 53 = 39.75 cubic inches of C4*  **NOTE:** Length of cut is 53".
Step 3	Divide by RE factor, if required: No required because only C4 or sheet explosives are used.
Step 4	Divide by package weight/volume and round UP to next whole package: $N = \frac{Charge\ Volume}{Package\ Volume} = \frac{39.75}{20} = 1.98$ Round up to 2 packages of C4.
Step 5	Calculate number of charges: *One I-beam = 1 Charge*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 2 x 1 = 2 packages of C4*
Solution: Two packages of C4 are required to cut the I-beam. For placement of charge, see Figure 3-12 (page 3-13).	

Example A-6. Steel-cutting charge claculation (I-beam)

Problem: Determine the quantity of C4 required to cut a 7-inch steel bar using a saddle charge.	
Step 1	Obtain the critical dimensions: a. Target Diameter = 7 inches b. Target Circumference = 3.14 x 7 = 21.98 inches
Step 2	Calculate for TNT/Rule of Thumb: a. Thickness = 1.00 inch. b. Base Width = 1/2 (Target circumference) = 10.99 inches. c. Long Axis = Target Circumference = 21.98 inches. d. Total Volume = 1/2 (Base Width)(Long Axis) = 120.78 cubic inches.
Step 3	Divide by RE factor, if required: Not required because only C4 of sheet explosives are used.
Step 4	Divide by package weight/volume and round UP to next whole package: $N = \frac{Charge\ Volume}{Package\ Volume} = \frac{120.78}{20} = 6.039$ Round up to 7 packages of C4.
Step 5	Calculate number of charges: One Bar = One Charge
Step 6	Calculate total amount of explosives: Step 4 x Step 5 = Total Packages = 7 x 1 = 7 packages of C4
Solution: Seven packages of C4 are required to cut the steel bar using a saddle charge. For placement of charge, see Figure 3-13 (page 3-14).	

Example A-7. Steel-cutting charge calculation (steel bar)

Problem: Determine the quantity of C4 required to cut a 9-inch, high-carbon-steel bar using a diamond charge.	
Step 1	Obtain critical dimensions: a. Target Diameter: 9 inches. b. Target Circumference: 3.14 x 9 = 28.26 inches.
Step 2	Determine the required charge dimensions: a. Thickness: 1.00 inch. b. Short Axis: 1/2 (Target Circumference) = 14.13 inches. c. Long Axis: Target Circumference = 28.26 inches. d. Total Volume: 1/2 (Thickness x Long Axis x Short Axis) = 199.65 cubic inches.
Step 3	It is not necessary to determine the equivalent amount of C4 because this charge uses and is computed for plastic explosive (C4), not TNT.
Step 4	Determine the number of required packages of C4: $N = \frac{Charge\ Volume}{Package\ Volume} = \frac{199.65}{20} = 9.98$ (*Round up to* 10)
Step 5	Determine the number of charges required. The 9-inch, high-carbon steel bar requires only one charge.
Step 6	Determine the total number of packages required: *Packages* (*Step* 4) *X Charges* (*Step* 5) = *Total Packages*
Solution: Since only one charge is required to cut the high-carbon steel bar, you will need 10 packages of C4 to cut the steel bar. For placement of charge, see Figure 3-14 (page 3-15).	

Example A-8. Steel-cutting charge calculation (high-carbon steel)

Problem: Using the formula R^3KC, determine the number of Composition-C4 packages required to breach a reinforced-concrete pier, 5 feet thick and 30 feet wide. The charges will be elevated 5 feet and untamped.	
Step 1	Obtain the critical dimensions: a. *Breaching Radius (R) = 5 feet.* b. *Pier Width (W) = 30 feet.*
Step 2	Calculate for TNT/Rule of Thumb: $P = R^3KC = 5^3(0.54)1.8 = 121.50$ *pounds of TNT*
Step 3	Divide by RE factor, if required: $\frac{121.5}{1.34} = 90.67$ *pounds of C4*
Step 4	Divide by package weight/volume and round UP to next whole package:: $N = \frac{Charge\ Weight}{Package\ Weight} = \frac{90.67}{1.25} = 72.53$ Round up to 73 packages of C4.
Step 5	Calculate number of charges:: $N = \frac{W}{2R} = \frac{30}{2(5)} = 3$ *charges*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 73 x 3 = 219 packages of C4*
Solution: 219 packages of C4 are required to breach the pier. For placement of charge, see Figure 3-16 (page 3-19).	

Example A-9. Breaching charge calculation (reinforced-concrete pier)

Problem: Determine the required amount of C4 needed to counterforce four concrete cubes three feet thick.	
Step 1	Obtain critical dimensions: *Circumference of Target = 3 feet*
Step 2	Calculate for TNT/Rule of Thumb: *P = 1 1/2 pounds of C4 per foot of diameter* *P = 1 1/2 x 3 = 4.5 pounds of C4*
Step 3	Divide by RE factor, if required: Not required because only C4 or sheet explosives are used.
Step 4	Divide by package weight/volume and round UP to next whole package: $N = \frac{Charge\ Weight}{Package\ Weight} = \frac{4.5}{1.25} = 3.6$ Round up to 4 packages of C4
Step 5	Calculate number of charges: *Four Cubes = Four Charges*
Step 6	Calculate total amount of explosives: *Step 4 x Step 5 = Total Packages = 4 x 4 = 16 packages of C4*
Solution: 16 packages of C4 are required to counterforce four cubes. For placement of charges, see Figure 3-17 (page 3-20).	

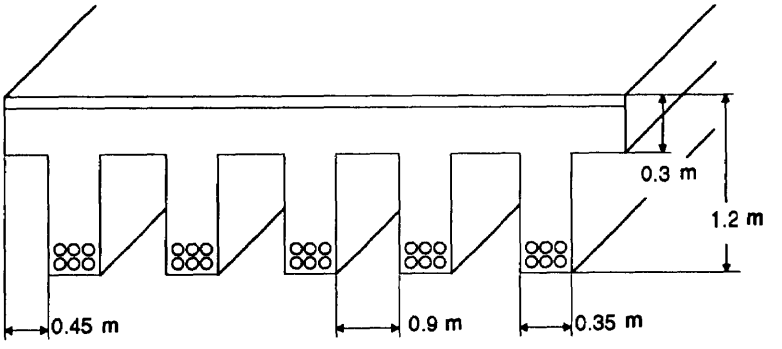
Example A-10. Counterforce charge calculation

Problem: Determine the quantity of cratering charges and C4 required to create a deliberate crater 146 feet long.	
Step 1	Obtain critical dimensions: *Crater Length (L) = 146 feet*
Step 2	Calculate for TNT/Rule of Thumb: a. *7-Foot Borehole = 80 pounds* b. *5-Foot Borehole = 40 pounds + 1 pound for dual priming*
Step 3	Divide by RE factor, if required: Not required
Step 4	Divide by package weight/volume and round UP to next whole package:: a. *7-Foot Borehole = 2 cratering charges* b. *5-Foot Borehole = 1 cratering charge and 1 package of C4.*
Step 5	Calculate number of charges: $N = \frac{L-16}{5} + 1 = \frac{146-16}{5} + 1 = 27$ *Holes* 27/2 = 13.5; round up to 14 for 7-foot holes and round down to 13 for 5-foot holes
Step 6	Calculate total amount of explosives: a. 7-Foot Boreholes: 2 charges x 14 boreholes = 28 cratering charges b. 5-Foot Boreholes: 1 charge x 13 boreholes = 13 cratering charges and 13 packages C4 Total = 41 cratering charges and 13 packages of C4
Solution: 41 cratering charges and 13 packages of C4 are needed to create a deliberate crater 146 feet long. For charge placement, see Figure 3-19 (page 3-23).	

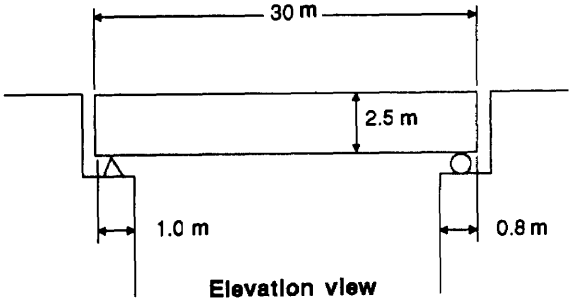
Example A-11. Cratering charge calculation

A-3. Demolition Calculation.

Problem: A simply supported, reinforced-concrete, beam-and-slab span must be destroyed with a concrete-stripping charge. The diagram below shows the span dimensions. Determine the quantity of C4 required and the resulting ditch width.



Cross section at midspan



Elevation view

Beam Calculations	
Step 1	Determine the amount of TNT required per meter: $P = 3.3(3.3h + 0.5)^3 = 3.3[3.3(1.2) + 0.5]^3 = 292.76$ *pounds TNT per meter*
Step 2	Determine the amount of explosive (TNT) per beam: P = (*Pounds* $^{TNT/meter}$)(*Beam width, in meters*) $P = 292.76(0.35) = 102.47$ *pounds per beam*
Step 3	Determine the equivalent amount of C4: $\frac{P}{RE} = \frac{102.47}{1.34} = 76.47$ *pounds C4 per beam*
Step 4	Determine the required packages of C4 per beam: $N = \frac{Charge\ Weight}{Package\ Weight} = \frac{76.47}{1.25} = 61.18$ (*Round up to* 62)
Slab Calculations	
Step 1	Determine the amount of TNT required per meter of slab between beams: $P = 3.3(3.3h + 0.5)^3 = 3.3[3.3(0.3) + 0.5]^3 = 10.92$ *pounds TNT per meter*
Step 2	Determine the amount of TNT required per slab: P = (*Pounds TNT per meter*) (*Slab width, in meters*) $= 10.92(0.9) = 9.83$ *pounds TNT*

Example A-12. Beam-and-slab bridge demolition calculation

Step 3	Determine the equivalent amount of C4: $\frac{P}{RE} = \frac{9.83}{1.34} = 7.34$ *pounds C4 per slab*
Step 4	Determine the required packages of C4 per slab: $N = \frac{\textit{Charge Weight}}{\textit{Package Weight}} = \frac{7.34}{1.25} = 5.87$ (*Round up to* 6)

Total Charge

$P = 5(\textit{Beam Charge}) + 5(\textit{Slab Charge}) = 5(62) + 5(6) = 310 + 30 = 340$ *packages of C4*

Ditch Width

$W_d = 2h + 0.3 = 2(1.2) + 0.3 = 2.7$ *meters*

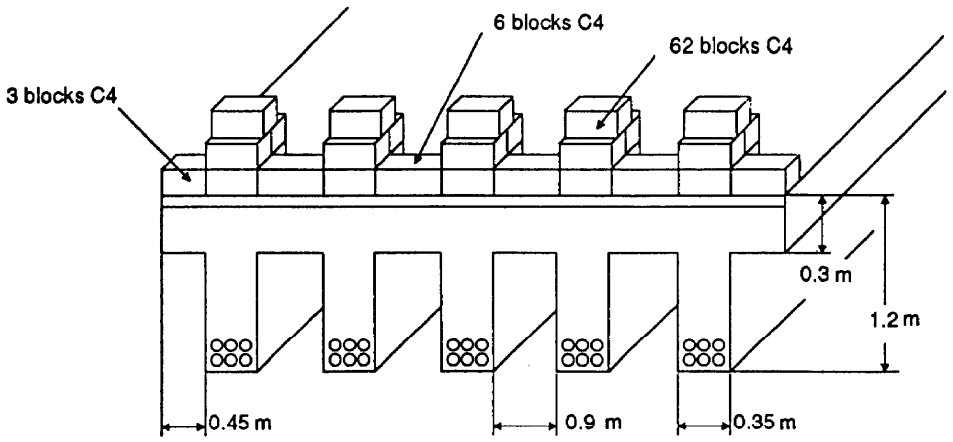
$\frac{H}{L} = \frac{2.5}{30} = 0.0833$ meters

$\frac{L_s}{L} = \frac{0.9}{30} = 0.03$ meters

From Table 4-2 (page 4-18), $\frac{L_c}{L} = 0.060$ meters.

Therefore, $L_c = 0.060\ (30) = 1.8$ meters.

Since $L_c < W_d$, use $P = 340$ packages of C4, as calculated.

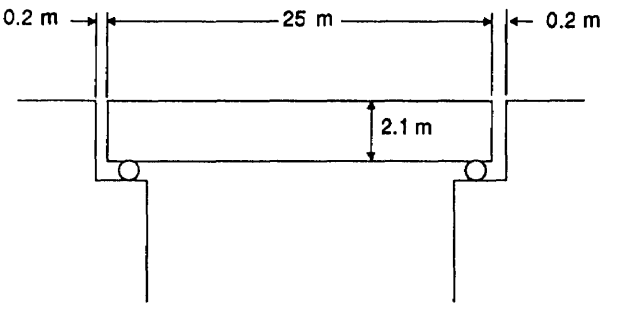


Example A-12. Beam-and-slab bridge demolition calculation (continued)

A-4. Attack Calculations.

Problem: Determine the attack method for demolishing a simply supported, steel-beam bridge with bottom supports and the following measurements:

a. Length (L): 25.0 meters.
b. Height (H): 2.1 meters.
c. End Clearance (E): 0.4 meters.



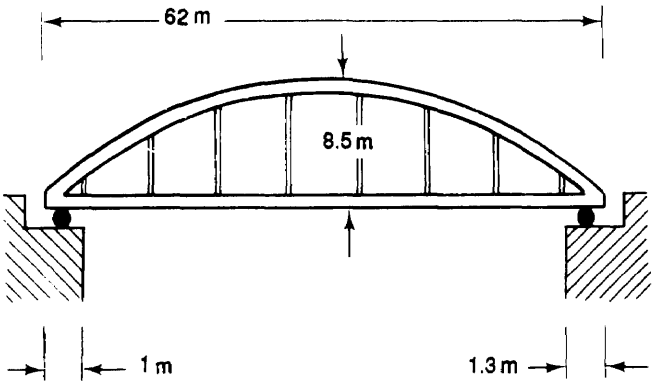
Step 1	Consult Appendix H. Table H-1 (page H-1) lists bottom attack method for this bridge, provided that the actual end clearance (*E*) is greater than *E*.
Step 2	Perform the calculation to determine whether *E* is greater than E_R. a. Determine the height-to-length ratio (*H*/*L*): $\frac{H}{L} = \frac{2.1}{25} = 0.084$ b. Find the corresponding *E*/*L* value (Table H-1, page H-1). Since 0.084 is not found on the table, round UP to 0.09. (interpolate, if necessary). c. Determine the required end clearance. Use the following formula to find *E*. $E_R = (\frac{E_R}{L})L = 0.016(25) = 0.40$ *meters*

Solution: Compare the actual and required end clearances. Since the actual end clearance (0.4 meters) is equal to the required end clearance (0.40 meters), a bottom attack is possible without any likelihood of the span jamming.

Example A-13. Bottom attack calculation

Problem: Determine the attack method for demolishing a simply supported, bowstring bridge with the following measurements:

a. Length (L): 62.0 meters.
b. Height (H): 8.5 meters.
c. Average Length of Bearing Supports (L_S): 1.15 meters.



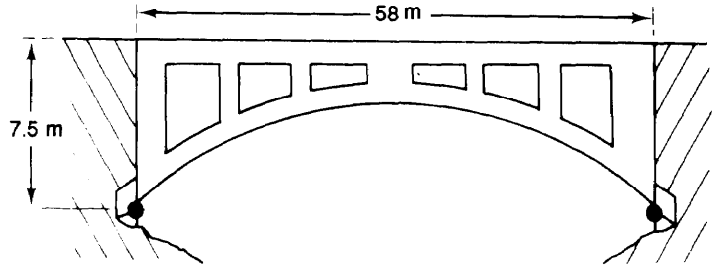
Step 1	Consult Appendix H. Table H-2 (page H-2) lists the top attack method for this bridge.
Step 2	Determine the height-to-length ratio (H/L). Since 0.137 is not found on the table, round UP to 0.014. $\frac{H}{L} = \frac{8.5}{62} = 0.137$
Step 3	Determine the required-gap ratio (L_S/L). $\frac{L_S}{L} = \frac{1.15}{62} = 0.0186$
Step 4	Find the corresponding L_S/L value (Table H-2, page H-2). Since 0.0186 is not found on the table, round UP to 0.020.
Step 5	a. Intersect the L_S/L and H/L values on the table to get the value of L_C/L. $L_C/L = 0.082$. b. Multiply the L_C/L value by the length to get L_C. $L_C = 0.082 \times 62 = 5.08$ meters.
Step 6	Determine where to place the charges. To accomplish this, divide L_C in half (5.08/2 = 2.54 meters).

Solution: The proposed cut must be 2.54 meters from either side of midspan. Mark the bridge in this location. This location is the centerline for the proposed cut.

Example A-14. Top attack calculation

Problem: Determine the attack method for a continuous, concrete-arch bridge with open spandrels and pinned footings, having the following measurements:

a. Length (*L*): 58.0 meters.
b. Rise (*H*): 7.5 meters.



Step 1	Consult Appendix H. Table H-2 (page H-2) lists the bridge attack method for this bridge.
Step 2	Determine the height-to-length ratio (*H*/*L*): $\frac{H}{L} = \frac{7.5}{58} = 0.129$
Step 3	Find the corresponding L_c/L value (Table 4-1, page 4-20). Since 0.129 is not found on the table, round UP to 0.14. The value found below 0.14 is 0.04.
Step 4	Determine the required length of the cut: $L_c = \frac{L_c}{L}(L) = (0.04)58 = 2.32$ *meters*
Step 5	Determine where to place the charges. Place charges at the midspan.

Solution: The proposed cut must be at the midspan. Mark the bridge in this location. This location is the centerline for the proposed cut.

Example A-15. Arch bridge attack calculation

Appendix B
Metric Charge Calculations

B-1. Equivalent Metric Weights for Standard Explosives. NATO requirements make metric conversions necessary. The following formulas are metric equivalents for charge calculations. Table B-1 lists the metric equivalents for standard US Army demolition charges.

Table B-1. Standard US demolition charges (metric equivalents)

Explosive	Unit (Pounds)	Detonation Velocity		RE Factor	Weight (Metric) (Kilograms)
		M/Sec	Ft/Sec		
TNT	0.25	6,900	22,600	1.00	0.113
	0.50	6,900	22,600	1.00	0.227
	1.00	6,900	22,600	1.00	0.454
M2 Tetrytol	2.50	7,000	22,900	1.20	1.134
M3 Comp C2 or C3	2.25	7,625	25,000	1.34	1.021
M5A1 Comp C4	2.50	8,040	26,400	1.34	1.134
M112 Block (C4)	1.25	8,040	26,400	1.34	0.567
M118 Block (PETN)	2.00	7,040	23,600	1.14	0.907
M118 Sheet (PETN)	0.25	7,040	23,600	1.14	0.113
M186 Roll (PETN)	25.00	7,040	23,600	1.14	11.34
Ammonium Nitrate	43.00	3,400	11,000	0.42	18.14
M1 Dynamite	0.50	6,100	20,000	0.92	0.227
M2A4 Shaped Charge	15.00	NA	NA	NA	6.80
M3A1 Shaped Charge	40.00	NA	NA	NA	18.14
M183 Assembly	NA	NA	NA	1.34	9.07

B-2. Timber-Cutting Formulas. The formulas on the following pages are examples of charge calculations converted to their metric equivalents.

a. *Tamped Internal Charges.*

$$K = \frac{D^2}{3{,}500} \quad \text{(B-1)}$$

where—

K = *TNT required, in kilograms.*
D = *timber diameter, in centimeters.*

b. *Untamped External Charges.*

$$K = \frac{D^2}{560} \quad \text{(B-2)}$$

where—

K = *TNT required, in kilograms.*
D = *timber diameter, in centimeters.*

c. *Abatis Charges.*

$$K = \frac{D^2}{700} \quad \text{(B-3)}$$

where—

K = *TNT required, in kilograms.*
D = *timber diameter, in centimeter.*

B-3. Steel-Cutting Formulas. Table B-2 gives the correct metric weight of TNT necessary to cut structural steel sections of various dimensions. Use Table B-2 or use the following formulas:

a. *Structural Steel.*

$$K = \frac{A}{38} \quad \text{(B-4)}$$

where—

K = TNT required, in kilograms.
A = cross-sectional area of the steel, in square centimeters.

b. *Other Steel.*

$$K = \frac{D^2}{14} \quad \text{(B-5)}$$

where—

K = *TNT required, in kilograms.*
D = *section diameter, in centimeters.*

Table B-2. TNT steel-cutting charges (metric)

Average Section Thickness (cm)	Section Width (cm)											
	4	6	8	10	15	20	25	30	35	40	50	60
0.5	0.06	0.08	0.11	0.13	0.20	0.27	0.33	0.40	0.46	0.53	0.66	0.79
1.0	0.11	0.16	0.21	0.27	0.40	0.53	0.66	0.79	0.93	1.06	1.32	1.58
1.5	0.16	0.24	0.32	0.40	0.60	0.79	0.99	1.19	1.39	1.58	1.98	2.37
2.0	0.21	0.32	0.42	0.53	0.79	1.06	1.32	1.58	1.85	2.11	2.64	3.16
2.5	0.27	0.40	0.53	0.66	0.99	1.32	1.65	1.98	2.31	2.64	3.29	3.95
3.0	0.32	0.48	0.64	0.79	1.19	1.58	1.98	2.37	2.77	3.16	3.95	4.74
3.5	0.37	0.56	0.74	0.93	1.39	1.85	2.31	2.77	3.23	3.69	4.61	5.53

B-4. Pressure Charges for T-Beams. Use the following formula to determine the metric size of T-beam pressure charges:

$$K = 48H^2T \quad \text{(B-6)}$$

where—

K = *TNT required, in kilograms.*
H = *T-beam height, in meters.*
T = *beam thickness, in meters.*

NOTE: Measure *H* and *T* to the nearest 0.1 meter, but no less than 0.3 meter. Minimum tamping required is 30 centimeters. Increase K by one third for untamped charges.

B-5. Breaching Charges.

$$K = R^3MC \quad \text{(B-7)}$$

where—

K = *TNT required,* in *kilograms.*
R = *breaching radius, in meters (Chapter 3, page 3-17).*
M = *material factor (Table B-3, page B-4).*
C = *tamping factor (Figure 3-16, page 3-19).*

a. *Breaching Radius.* The breaching radius is the distance a charge must penetrate to displace or destroy the target. For example, to determine the breaching radius for a 2.9-meter concrete wall with a charge placed on its side, use 3.0 as the breaching radius in the formula above. Always round the target's depth to the next higher quarter meter (2.9 becomes 3.0, 2.54 becomes 2.75, and so forth).

b. *Material Factor.* Table B-3 (page B-4) lists material factors.

c. *Tamping Factor.* The value of the tamping factor depends on the location and tamping of the charge. A charge is not adequately tamped unless the tamping material's depth equals or exceeds the breaching radius. Figure 3-16 (page 3-19) gives values for the tamping factor.

Table B-3. Material factors (*M*) for breaching charges (metric)

Material	Breaching Radius (*R*)	*M*
Earth	All values	1.12
Poor masonry Shale Hardpan Good timber Earth construction	Less than 1.5 m 1.5 m or more	5.13 4.64
Good masonry Concrete block Rock	0.3 m or less Over 0.3 m to less than 1 m 1 m to less than 1.5 m 1.5 m to less than 2 m 2 m or more	14.09 7.69 6.41 5.13 4.32
Dense concrete First-class masonry	0.3 m or less Over 0.3 m to less than 1 m 1 m to less than 1.5 m 1.5 m to less than 2 m 2 m or more	18.26 9.93 8.33 6.57 5.61
Reinforced concrete (Factor does not consider cutting of concrete)	0.3 m or less Over 0.3 m to less than 1 m 1 m to less than 1.5 m 1.5 m to less than 2 m 2 m or more	28.19 15.38 12.81 10.09 8.65

Appendix C
Use of Demolition Charges

C-1. Sources.

a. *Primary Charges.* When using land mines, aerial bombs, shells, and foreign explosives as demolition charges, take the appropriate precautions outlined in the paragraphs below. The use of such explosives is usually uneconomical but may occasionally become necessary or desirable. Obtain such materials from captured or friendly supply stocks or, in the case of land mines, those recovered from enemy or friendly minefield. Never use unexploded duds (shells or bombs) for demolition purposes.

b. *Supplementary Charges.* When necessary, use allied-nation or captured explosives to supplement or replace standard explosive charges.

C-2. Land Mines.

a. *Safety Precautions.* Use only defused mines as demolition charges. Recovered mines may be sensitive because of near misses and may detonate during normal handling. The theater commander prescribes the policy for use of salvaged or captured threat mines.

b. *Charges.* When calculating charges using mines, consider only the explosive weight. Use normal explosive quantities for cratering or pressure charges. However, the mine case does not allow proper contact of the explosives against irregularly shaped objects. You may find it necessary to increase the size of cutting charges considerably when using mines for this purpose. Test shots are the best way to determine the proper charge under given conditions. Table C-1 (page C-2) lists the explosives content of various antitank mines by country of origin. The US mines are current; foreign mines may be current or obsolete.

c. *Priming.* Detonate a land mine by placing a l-pound charge on the pressure plate. If firing large quantities of mines simultaneously, prime several mines to ensure complete detonation. Detonating a single mine normally detonates any other mine in direct contact with the primed mine.

C-3. Aerial Bombs.

a. *Safety Precautions.* General-purpose, aerial bombs make satisfactory demolition charges but are more effective as cratering charges. Their shape makes them inefficient for demolitions requiring close contact between the explosive and the target. Take precautions against fragmentation, as the steel fragments from bomb cases may fly great distances. Before using any bomb, positively identify it as a general-purpose bomb.

Table C-1. Antitank (AT) mine explosives content (by nation)

Country	Mine Type	Weight/Explosive
United States	M15 AT (Metallic)	22 lb/TNT
	M19 AT (Nonmetallic)	21 lb/TNT
	M21 AT (Metallic)	10.5 lb/Comp H6
Belgium	PRB-4 AT	20 lb/Hexogen
Communist China	Dual-Purpose No. 4 (Metallic)	4.5 lb/TNT
Czechoslovakia	PT-Mi-K AT (Metallic)	11 lb/TNT
	PT-Mi-Ba AT (Plastic)	12 lb/TNT
	Na-Mi-Ba AT (Plastic)	5.3 lb/Tritol
	TQ-Mi AT (Cardboard)	11.5 lb/TNT
Finland	M36 AT (Metallic)	8 lb/TNT
	M39 AT (Metallic)	8.8 lb/TNT
France	M1948 AT (Metallic)	11.5 lb/TNT or Military Dynamite
	M1948 Plate Charge AT (Metallic)	15.2 lb/TNT or Picric Acid
	M1951 Shaped Charge AT (Metallic)	4 to 5 lb/Kexolite
	M1951 AT (Caseless)	14.3 lb/TNT (Cast)
	M1951 AT (Plastic "grille")	11 to 16 lb/PETN
Japan	Model 63 Heavy AT	24.2 lb/Comp B
Netherlands	Type II AT (Metallic)	9 lb
South Korea	Heavy AT (Metallic)	22 lb/TNT
	Type I Dual Purpose (Metallic)	5.7 lb/TNT
	Type II Dual Purpose (Metallic)	4.5 lb/TNT
Former Soviet Union	TMD-B AT (Wooden)	11 to 15 lb/Amatol, DTNT, or Picric Acid*
	TMN-46 AT (Metallic)	12.6 lb/TNT
	YaM-5 AT	8 to 11 lb/TNT or Amatol
United Kingdom	Mark 4 GS AT (Metallic)	8.25 lb/TNT
	Mark 5 GS AT (Metallic)	4.5 lb/TNT
	Mark 5 HC AT (Metallic)	8.3 lb/TNT
	Mark 7 AT (Metallic)	19.6 lb/TNT

*Picric acid corrodes metals, forming extremely sensitive compounds that are easily detonated. Do *not* handle mines loaded with this explosive except to move them to a safe disposal area for destruction.

b. *Charges.* The explosive content of an aerial bomb is approximately half its total weight. Table C-2 lists the explosives content for various general-purpose bombs. Approximately 20 percent of the explosive potential of an aerial bomb is expended in shattering the casing.

c. *Priming.* Detonate bombs under 500 pounds by placing a 5-pound explosive charge on the middle of the casing; bombs exceeding 500 pounds require a 10-pound charge. Do not place fuses on the nose or tail of the bomb. To ensure detonation, prime large bombs separately.

Table C-2. General-purpose, aerial bombs (explosive contents)

Bomb	Explosive Weight	Total Weight
Old Series		
AN-30A1, 100-pound GP	57	120
AN-M57A1, 250-pound GP	125	261
AN-M64A1, 500-pound GP	266	549
AN-M65A1, 1,000-pound GP	555	1,064
AN-M66A2, 2,000-pound GP	1,098	2,113
New Series		
M117, 750-pound GP	386	823
M118, 3,000-pound GP	1,975	3,049
Low-Drag		
MK81, Mod 1, 250-pound GP	100	260
MK82, Mod 1, 500-pound GP	192	531
MK83, Mod 3, 1,000-pound GP	445	985
MK84, Mod 1, 2,000-pound GP	945	1,970
Low-Drag, Snakeye I		
MK81, Mod 1, 250-pound GP	100	300
MK82, Mod 2, 500-pound GP	192	560

C-4. Artillery Shells (Nonnuclear).

a. *Safety Precautions.* Use artillery shells for demolition when only fragmentation is desired. Because of their low explosive content, artillery shells are generally not adequate for other demolition purposes.

b. *Charges.* Any artillery shell fits this category; however, avoid shells smaller than 100 millimeters. The 105-millimeter howitzer, high-explosive shell, which weighs 33 pounds, contains only 5 pounds of explosive. The 155-millimeter howitzer shell contains only 15 pounds of explosive.

c. *Priming.* Detonate shells up to 240 millimeters by placing 2-pound charges on the case, just forwar of the rotating band. To ensure complete detonation of multiple shells simultaneously, place a charge on each shell. Use the M10 universal destructor to detonate shells that have threaded

fuse wells of 1.7- or 2-inch diameters. Fill the booster cavities of bombs and large projectiles fully by adding booster cups to the M10 destructor, as required.

C-5. Foreign Explosives.

a. *Safety Precautions.* Use foreign explosives to supplement standard US charges or, in certain cases, instead of US charges. However, only experienced demolition personnel should work with such explosives and then only according to instructions and directives issued by the theater commander. TM 9-1300-214 lists the most common foreign explosives.

b. *Priming.* Most foreign explosive blocks have cap wells large enough to receive US military blasting caps. However, test fire these charges with US military blasting caps to ensure positive detonation. In certain instances, you may find it necessary to initiate the explosives by using a standard US demolition block primed with a blasting cap.

Appendix D
Expedient Demolitions

D-1. Expedient Techniques. These techniques are intended for use only by personnel experienced in demolitions and demolitions safety. Do not use expedient techniques to replace standard demolition methods. Availability of trained soldiers, time, and material are the factors to consider when evaluating the use of expedient techniques.

D-2. Shaped Charges.

a. *Description.* Shaped charges concentrate the energy of the explosion released on a small area, making a tubular or linear fracture in the target. The versatility and simplicity of shaped charges make them effective against many targets, especially those made of concrete or those with armor plating. You can improvise a shaped charge (Figure D-l). Because of the many variables (configuration, explosive density, liner cavity density, and so forth), consistent results are impossible to obtain. Therefore, experiment to determine the optimum standoff distances. Plastic explosive is best suited for this type of charge. However, dynamite and molten TNT can be effective expedients.

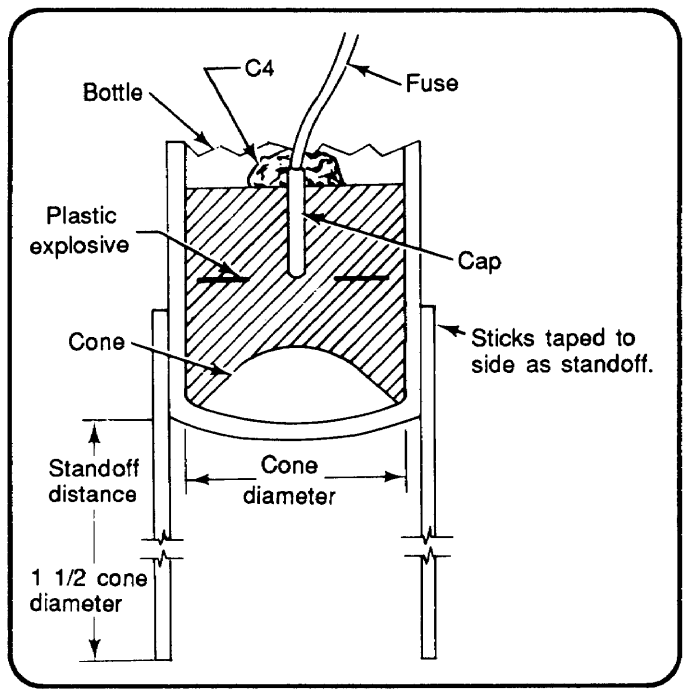


Figure D-1. Improvised shaped charge

b. *Fabrication.* Obtain a container for the shaped charge and remove both ends. Almost any kind of container will work. Cans, jars, bottles, or drinking glasses will do. Some containers come equipped with built-in cavity liners, such as champagne or cognac bottles with the stems removed. With the ends removed, the container is ready for a cavity liner and explosive. Optimum shaped-charge characteristics are:

(1) Cavity Liner. Make a cone-shaped cavity liner for the container from copper, tin, zinc, or glass. Funnels or bottles with a cone in the bottom (champagne or cognac bottles) are excellent. However, if material is not available for a cavity liner, a workable but less effective shaped charge can be made by cutting a coned-shaped cavity in a block of explosive.

(2) Cavity Angle. For most high-explosive antitank (HEAT) ammunition, the cavity angle is 42 to 45 degrees. Expedient charges will work with cavity angles between 30 and 60 degrees.

(3) Explosive Height (In Container). The explosive height is two times the cone height, measured from the base of the cone to the top of the explosive. Press the explosive into the container, being careful not to alter the cavity angle of the cone. Ensure the explosive is tightly packed and is free of any air pockets.

(4) Standoff Distance. The normal standoff distance is one and one-half cone diameters. Use standoff sticks to achieve this.

(5) Detonation Point. The exact top center of the charge is the detonation point. Cover the blasting cap with a small quantity of C4 if any part of the blasting cap is exposed or extends above the charge.

NOTE: Remove the narrow neck of a bottle or the stem of a glass by wrapping it with a piece of soft, absorbent twine or by soaking the string in gasoline and lighting it. Place two bands of adhesive tape, one on each side of the twine, to hold the twine firmly in place. To heat the glass uniformly, turn the bottle or stem continuously with the neck up. After the twine or plastic has burned, submerge the neck of the bottle in water and tap it against some object to break it off. Tape the sharp edge of the bottle to prevent cutting hands while tamping the explosive in place. A narrow band of plastic explosive placed around the neck and burned gives the same results as using string or twine.

D-3. Platter Charge. This device uses the Miznay-Shardin effect. It turns a metal plate into a powerful, blunt-nosed projectile (Figure D-2). Use a round, steel platter, if available. Square platters also will work. The platter should weigh 2 to 6 pounds.

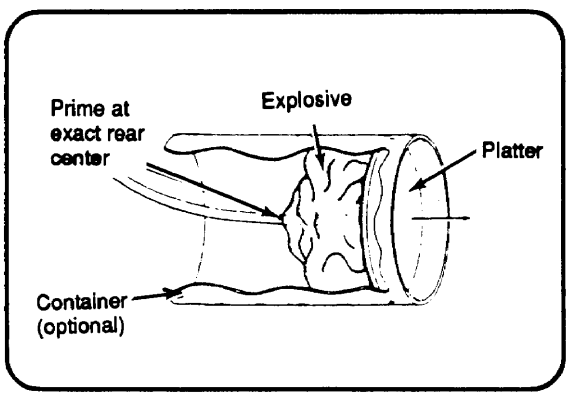


Figure D-2. Platter charge

a. *Charge Size.* Use a quantity of explosive equal to the platter weight.

b. *Fabrication.*

(1) Uniformly pack the explosive behind the platter. A container is not necessary if the explosive will remain firmly against the platter without a container. Tape is an acceptable anchoring material.

(2) Prime the charge at the exact, rear center. Cover the blasting cap with a small quantity of C4 if any part of the blasting cap is exposed.

(3) If available, use a gutted M60 fuze igniter as an expedient aiming device and aim the charge at the direct center of a target. Ensure the explosive is on the side of the platter opposite the target. With practice, you can hit a 55-gallon drum, a relatively small target, at 25 yards about 90 percent of the time with a platter charge.

D-4. Grapeshot Charge. This charge consists of a container (an ammo can or Number- 10 can), projectiles (nails, bolts, glass, small pieces of scrap metal, or rocks), buffer material (soil, leaves, felt, cloth, cardboard, or wood), a charge (plastic explosive like C4), and a blasting cap. Assemble these components as as shown in Figure D-3.

a. *Charge Size.* Use a quantity of explosive equal to one quarter the projectile weight.

b. *Fabrication.*

(1) Make a hole in the center of the bottom of the container large enough to accept a blasting cap.

(2) Place the components in the container in the following sequence:

(a) Explosive. Place the plastic explosive uniformity in the bottom of the container, remove all voids or air spaces by tamping with a nonsparking instrument.

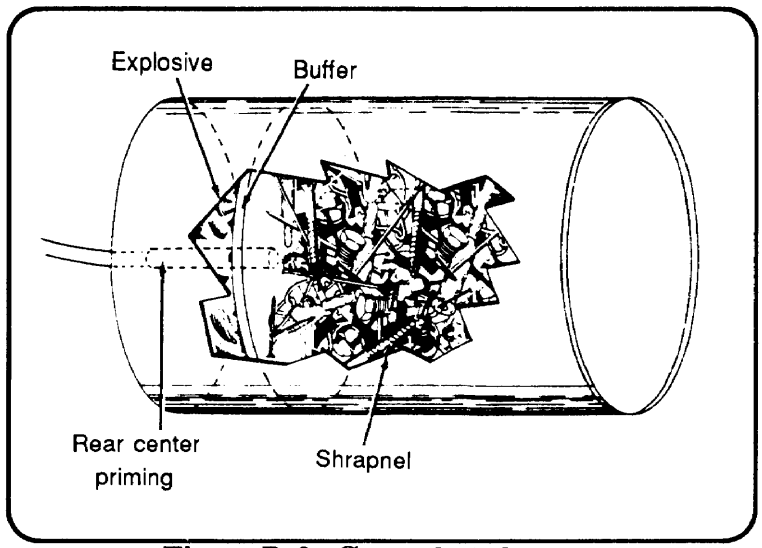


Figure D-3. Grapeshot charge

(b) Buffer. Place 2 inches of buffer material directly on top of the explosive.

(c) Projectiles. Place the projectiles on top of the buffer material, and place a covering over the projectiles to prevent them nom spilling out when handling the charge.

(3) Make a cap well in the plastic-explosive charge through the hole in the bottom of the container and insert the blasting cap of the initiation set. Cover the blasting cap with a small quantity of C4 if any part of the blasting cap is exposed

(4) Aim the charge at the center of the target from approximately 100 feet.

D-5. Dust Initiator. Dust-initiator charges use small quantities of explosives with larger amounts of powdered materials (dust or cover) to destroy thin-walled, wooden buildings or railroad boxcars. These charges work best in an enclosed area with few windows. At detonation, the dust or cover is distributed in the air within the target and ignited by an explosive-incendiary charge. The dust-initiator charge consists of an explosive, mixed with equal parts of incendiary mix, and a cover of finely divided organic material.

a. *Charge Computations.*

(1) Charge Size. One pound of explosive-incendiary mixture will effectively detonate up to 40 pounds of cover. To make a l-pound explosive-incendiary mixture, combine 1/2 pound of crushed TNT or C3 and 1/2 pound of incendiary mix (two parts aluminum powder or magnesium powder and three parts ferric oxide). Do not use C4 because the explosive component in C4 will not combine properly with the incendiary mixture.

(2) Cover (Dust) Size. Use 3 to 5 pounds of cover for each 1,000 cubic feet of target (3 pounds for enclosed buildings, 5 pounds for partially enclosed buildings). The cover can consist of coal dust, cocoa, powdered coffee, confectioners sugar, tapioca, wheat flour, corn starch, hard-rubber dust, aluminum powder, magnesium powder, powdered soap, or a volatile fuel such as gasoline.

b. *Fabrication.* Place the TNT or C3 explosive in a canvas bag and crush it into a powder with a wooden mallet. In the same bag that contains the crushed explosive, add an equal amount of incendiary mixture and mix thoroughly. Prime this explosive-incendiary charge with a detonating-cord knot. Place the primed charge in the center of the target and pour or place the cover on top of it, forming a pyramid. When using gasoline as the cover, do not use more than 3 gallons, since greater quantities will not evenly disperse in the air, giving poor results.

c. *Detonation.* The charge can be detonated by attaching initation sets to the detonating cord.

D-6. Improvised Cratering Charge. This charge consists of a mixture of ammonium nitrate fertilizer (at least 33.33 percent nitrogen) and diesel fuel, motor oil, or gasoline. The ratio of fertilizer and fuel is 25 pounds to 1 quart. The fertilizer must not be damp. You may fabricate almost any size of improvised charge from this mixture. Proceed as follows:

a. Measure the fertilizer and fuel for the size charge you require.

b. Add the fuel to the fertilizer and mix thoroughly.

c. Allow the fuel to soak into the fertilizer for an hour.

d. Place half of the ammonium nitrate charge in the borehole. Then, place two l-pound primed blocks of explosives in the borehole and add the remainder of the ammonium nitrate charge. Never leave the charge in the borehole for a long period, since the charge will accumulate moisture, reducing its effectiveness.

NOTE: Boreholes should receive 10 pounds of explosives for every foot of depth and must be dual primed.

e. Detonate the charge.

D-7. Improvised Borehole Method (Detonating-Cord Wick). This method (Figure D-4) is used to enlarge boreholes in soil. The best results are obtained in hard soil. Use the following procedure:

a. Tape together several strands of detonating cord 5 to 6 feet long. Generally, one strand enlarges the diameter of the hole by about one inch. Tape or tie the strands together into a wick for optimum results.

b. Make a hole by driving a steel rod approximately 2 inches in diameter into the ground to the depth required. According to the rule of thumb, a hole 10 inches in diameter requires 10 strands of detonating cord.

c. Place the detonating-cord wick into the hole using an inserting rod or some other field expedient. The strands must extend the full length of the hole.

d. Fire the cord either electrically or nonelectrically. An unlimited number of wicks can be fired atone time by connecting them with the detonating cord ring main or line main. If successive charges are placed in the holes, blowout excess gases and inspect the hole for excessive heat.

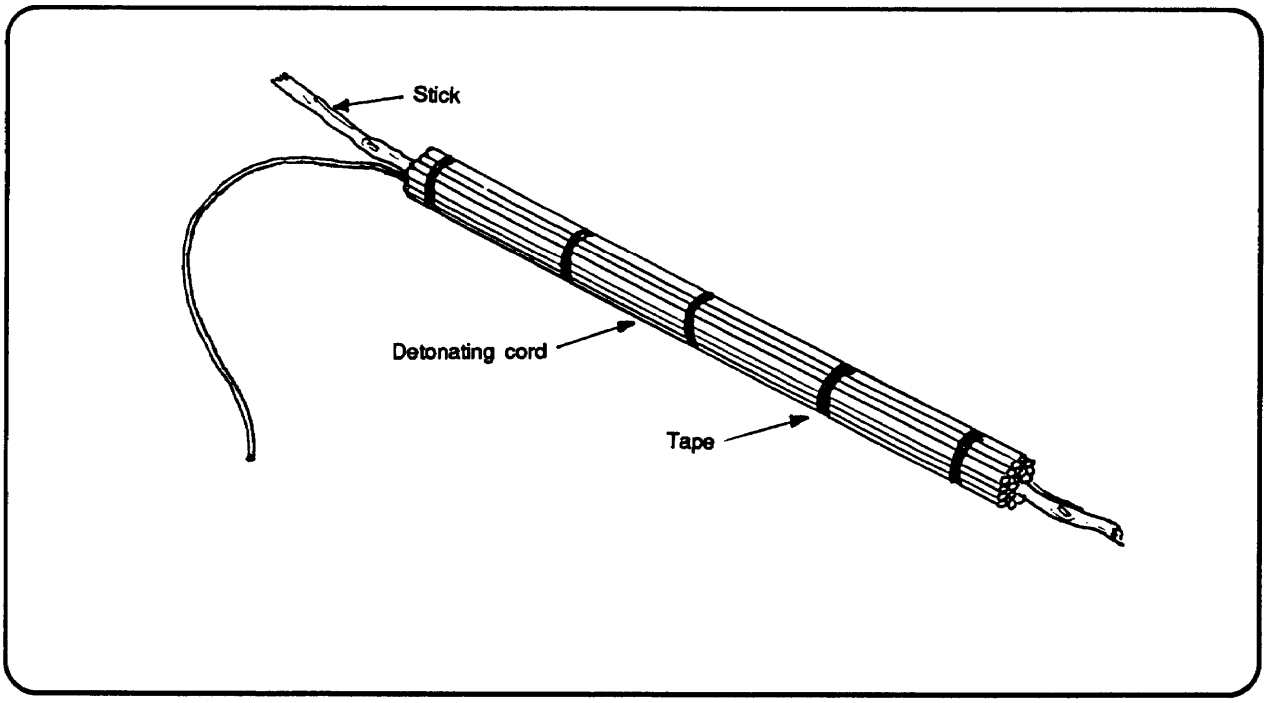


Figure D-4. Detonating-cord wick

D-8. Ammonium-Nitrate Satchel Charge. Although the satchel charge is excellent, it is mostly suitable for cratering. A more manageable charge may be used by mixing ammonium-nitrate fertilizer with melted wax instead of oil. The mixing ratio is 4 pounds of fertilizer to 1 pound of wax. Set the primer in place before the mixture hardens.

a. *Preparation.*

(1) Melt the wax in a container and stir in the ammonium-nitrate pellets, making sure that the wax is hot while mixing.

(2) Before the mixture hardens, add a 1/2-pound block of explosive primed with detonating cord. Ensure the primed charge is in the center of the mixture and that there is sufficient detonating cord available to attach initiation sets.

(3) Pour the mixture into a container. Add shrapnel material to the mixture if desired or attach the shrapnel on the outside of the container to give a shrapnel effect.

(4) Detonate the charge by attaching initiation sets to the detonating cord coming from the satchel charge.

b. *Use.* Because the wax and fertilizer may be molded into almost any size or shape, it may be applied to a great many demolition projects with satisfactory results.

D-9. Expedient Flame Fougasse. Use this device in defensive or offensive operations for its incendiary, illuminating, and signaling effects. The charge consists of a 55-gallon drum of thickened fuel, a kicker charge, a trip flare, and detonating cord (Figure D-5, page D-6). A 55-gallon drum containing a fougasse mixture is effective for a controlled-direction burst.

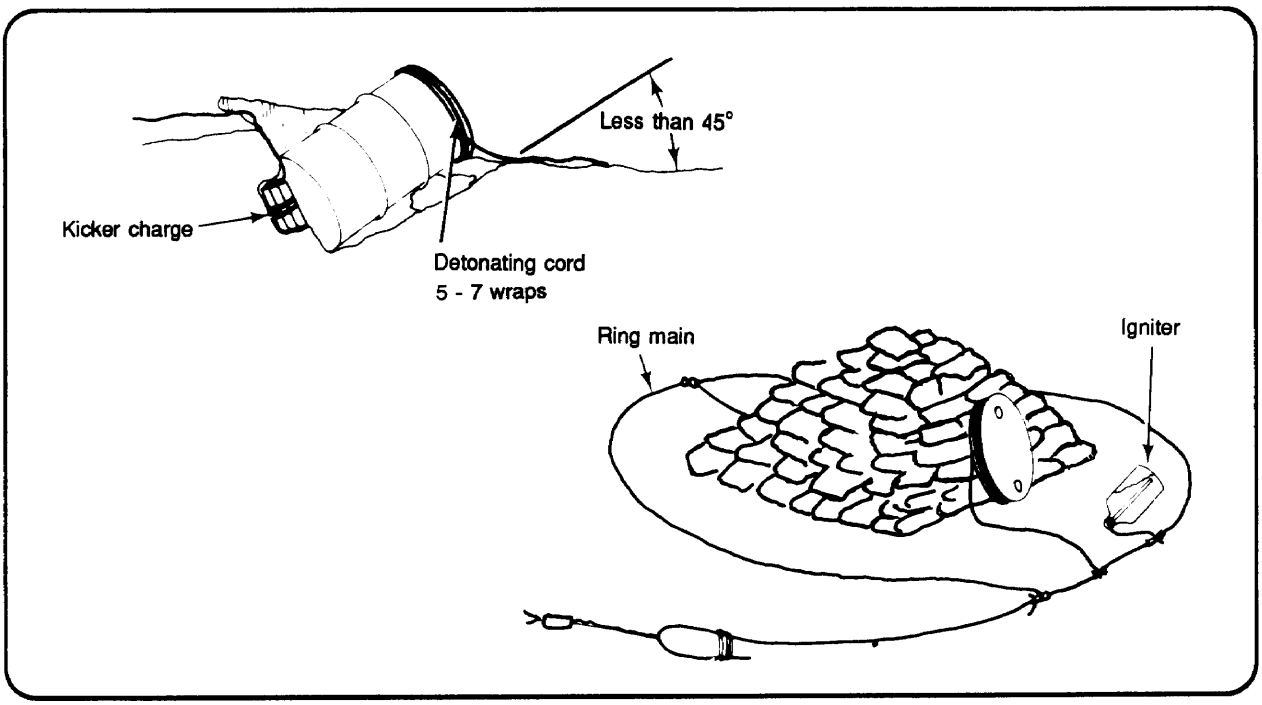


Figure D-5. Expedient flame fougasse

a. *Preparation.*

(1) Make the fougasse mixture by mixing 3 ounces of M4 thickening compound per gallon of gasoline or JP4 fuel. Depending on the temperature, the mixture may take from 15 minutes to several hours to thicken to the desired viscosity (resembling applesauce or runny gelatin). For a 55-gallon drum, vigorously mix 150 ounces of M4 thickening compound with 50 gallons of gasoline or JP4 fuel.

(2) Dig an angled trench for the 55 gallon drum that will allow the best coverage and dispersion of the flame fougasse. However, do not build the trench steeper than 45 degrees. Make a small cutout area in the back of the trench for the kicker charge (2 pounds of TNT or 2 blocks of C4).

(3) Prime the kicker charge with detonating cord, leaving 6 to 10 feet of detonating cord free to tie into a ring main (6 to 10 feet).

(4) Wrap the top end of the 55 gallon drum with 5 to 7 wraps of detonating cord, leaving 6 to 10 feet of the detonating cord free to tie into a ring main.

(5) Lay the drum in the trench and place the kicker charge in the small cutout. Push the drum against the back of the trench so the kicker charge seats firmly against the bottom of the drum. It may be necessary to tamp soil around the charge to properly center the kicker charge against the bottom of the drum. The running ends of detonating cord for the kicker charge and drum top should extend from the trench. Avoid kinks or sharp bends in the detonating cord.

(6) Lay out a ring main of detonating cord around the 55-gallon drum and tie the detonating cord from the kicker charge and wraps to the ring main.

(7) Cover the entire 55-gallon drum with a minimum of 1 foot of tamped soil, leaving the front of the drum exposed or uncovered.

(8) Using a length of detonating cord, tape one end under the spoon handle of an igniter trip flare (M49). Tape the spoon handle down securely, attach the trip flare to a stake, and position the stake 3 to 4 feet in front of the drum. Attach the free end of the detonating cord secured to the trip flare to the ring main. During combat, a WP grenade (M34) will work in place of the trip flare. If trip flares are not available, do the following:

- Take a 2-liter plastic bottle and fill it half full with raw gasoline or JP4 (unthickened).
- Punch a hole in the cap of the bottle and thread one end of a detonating cord through the hole.
- Tie a single overhand knot in the detonating cord to prevent it from being pulled back out of the cap.
- Place the detonating cord with the single overhand knot inside the bottle and secure the cap onto the bottle.
- Take the opposite end of the detonating cord and attach it to the ring main.

(9) Attach initiation sets to the ring main.

b. *Function.* When initiated, the ring main initiates the detonating cord to the trip flare, the drum top, and the kicker charge. The wraps cut the top of the drum off, the kicker charge propells the thickened fuel outward, and the trip flare ignites the thickened fuel as it travels downrange. The result is a flash of flame that spreads downrange for approximately 100 meters.

Appendix E
Power Requirements for Series Firing Circuits

E-1. Series Circuits. Electric blasting caps are connected in series and fried with an electric power source (blasting machine). A series circuit provides a single path for the electrical current that flows from one firing wire, through each blasting cap to the next blasting cap, and back to the other firing wire. A series circuit should not contain more than 50 blasting caps. The connection of more than 50 caps in a series circuit increases the chances of breaks in the firing line or cap leads.

E-2. Ohm's Law. *Ohm's Law* defines the amount of voltage necessary to detonate the blasting caps. Determine the required voltage for your firing circuit as follows:

$$E=IR \qquad \text{(E-1)}$$

where—

E = *electric potential, or voltage, in volts.*
I = *current, in amperes.*
R = *resistance, in ohms.*

E-3. Electric Power Formula. Determine the amount of electric power (watts) necessary to detonate blasting caps:

$$W=I^2R \qquad \text{(E-2)}$$

where—

W = electrical power, in watts.
I = *current, in amperes.*
R = *resistance, in ohms.*

E-4. Electric Blasting Caps. Military electric blasting caps connected in series require at least 1.5 amperes to fire, regardless of the number of caps in the series. The resistance of military electric blasting cap is 2 ohms.

E-5. Circuit Resistance. Ensure that the power source is adequate to fire all charges connected to the circuit. Firing wire, as well as blasting caps, contribute to total resistance in the circuit. Determine the amount of resistance by combining the individual resistances of the blasting caps and the wires. The resistance in the wire depends on the wire's size and length. Table E- 1 (page E-2) gives the resistance per 1,000 feet of various sizes of copper wire.

Table E-1. Resistance in copper wire

Wire Characteristics			Resistance per 1,000 Feet (Ohms)
AWG (B&S) Gauge No.	Diameter (In)	Weight (Lb/Ft)	
2	3/10	5.0	0.2
4	1/4	7.9	0.3
6	1/6	12.6	0.4
8	1/8	20.0	0.6
10	1/10	31.8	1.0
12	1/12	50.0	1.6
14	1/16	80.0	2.5
16	1/20	128.0	4.0
18	1/25	203.0	4.0
20	1/30	323.0	10.2
NOTE: For resistance, the ratings are for single-strand wire. Since blasting wire usually comes in double strands, use half its length to compute total resistance.			

E-6. Series Circuit Calculations. Complete calculations for any series circuit involved in determining the amount of current (amperes), voltage (volts), and power (watts) needed to fire the circuit. Use the following procedure:

a. *Current.* The current required for a series circuit of electric blasting caps is 1.5 amperes, regardless of the number of blasting caps in the circuit.

b. *Resistance.* Determine the resistance in the circuit (paragraph E-5, page E-l).

c. *Voltage.* Determine the required voltage for the circuit (paragraph E-2, page E- 1).

d. *Power.* Determine the required power for the circuit (paragraph E-3, page E-l).

e. *Example.* Determine the current, voltage, and power required to detonate a 20-cap series circuit consisting of special electric blasting caps and 500 feet of standard, 2-conductor, 18-gauge firing wire.

(1) Current. The amount of current required to detonate this circuit is 1.5 amperes

(2) Resistance.

Caps: 2.0 ohms (20 caps)= 40.0 ohms

Wire: 500 feet (2 strands)= 1,000 feet= 6.4 ohms (Table E-1)

Total Resistance: 46.4 ohms

NOTE: Number-18 wire consists of two strands. The example specifies a 500-foot piece of wire, so use 1,000 feet as the total wire length for determining resistance (500 x 2 = 1,000).

(3) Voltage.

$E = IR = 1.5(46.4) = 69.6$ *volts* (E-3)

where-

E = *voltage, in volts*
I = *current, in amperes*
R = *resistance, in ohms*

(4) Power.

$W = 1^2(R) = 1.5^2(46.4) = 104.4$ *WattS* (E-4)

where—

W = *power, in watts*
I = *current, in amperes*
R = *resistance, in ohms*

E-7. Voltage Drop. *Ohm's Law* allows you to determine the amount of voltage required (voltage drop) for a blasting circuit. In practice, the voltage drop should never exceed 90 percent of the available voltage; if it does, decrease the resistance or increase the voltage in the circuit to ensure that proper detonation occurs.

E-8. Blasting Machines. The name plate on power sources normally states the amperage and the voltage ratings. Before using any power source, determine whether it is suitable for your firing circuit. Generally, you can determine the adequacy of a power source by consulting Table E-2 (page E-4). This table lists the sizes of circuits that power sources can support. If you must determine the power source's capabilities from the name plate, use the following procedure:

a. *Determining Circuit Capacity*.

- Step 1. Multiply the power source's voltage rating by 90 percent to get an adjusted voltage rating.
- Step 2. Divide the adjusted voltage rating (Step 1) by the circuit's amperage rating (1.5 amperes). At this point you have the maximum allowable resistance in the circuit, in ohms.
- Step 3. Determine the total resistance from the firing wire (Table E-l).
- Step 4. Subtract the wire's resistance from the maximum allowable circuit resistance (Step 2) to determine the maximum allowable resistance of the blasting caps in the circuit.
- Step 5. Determine the maximum number of blasting caps the circuit will support by dividing the allowable resistance for caps (Step 4) by the resistance in one cap (2 ohms).

Table E-2. Power source capacities

Power Source	Circuit Size (Series)		
	10-Cap	30-Cap	50-Cap
Blasting Machine, 10-Cap	x	—	—
Blasting Machine, 30-Cap	x	x	—
Blasting Machine, 50-Cap	x	x	x
Generator, 1.5-kw, Portable (115V, 13.5A)	x	x	—
Generator, 3-kw, Portable (115V, 26A)	x	x	—
Generator, 5-kw, Portable (115V, 43.5A)	x	x	—
Generator, 3-kw, Portable (220V, 13.5A)	x	x	x
Generator, 5-kw, Portable (220V, 22.5A)	x	x	x

b. *Example.* Determine the maximum number of electric blasting caps allowed in a series circuit fired by a 220-volt, 13.5-ampere generator and 250 feet of double-strand, 20-gauge wire (a total of 500 feet of wire).

(1) Allowable Resistance.

$$\frac{0.90(220\ volts)}{1.5\ amperes} = 132\ ohms \qquad \text{(E-5)}$$

(2) Resistance in Firing Wire.

$$\frac{10.2\ ohms\ (500\ feet)}{1{,}000} = 5.2\ ohms \qquad \text{(E-6)}$$

(3) Allowable Resistance in Blasting Caps.

$$132\ ohms - 5.2\ Ohms = 126.8\ Ohms \qquad \text{(E-7)}$$

(4) Number of Blasting Caps.

$$\frac{126.8\ ohms}{2\ ohms} = 63.4\ caps\ (Round\ down\ to\ 63\ caps) \qquad \text{(E-8)}$$

E-9. Batteries and Dry Cells. Use the procedure in paragraph E-8 (page E-3) to determine the size of a circuit supported by a battery or dry cell.

Appendix F
Instructions for Completing Demolitions-Related Reports

F-1. Target Folder. A completed target folder contains demolition orders and an obstacle folder. A sample target folder is shown in Figure F-1 (page F-4). Refer to Chapter 5, Section III (page 5-2), for a discussion of the demolition orders. Refer to Chapter 5, Section IV (page 5-6) for a discussion of the obstacle folder.

F-2. Instructions for DA Form 2203-R. Use the following instructions and the sample form shown in Figure F-2 (pages F-38 through F-42) to complete DA Form 2203-R. A blank DA Form 2203-R is at the end of this manual. It may be locally reproduced on 8 1/2-by 11-inch paper.

a. *Block* 1 *(FILE NO.).* Leave blank unless a higher headquarters provides this number. Higher headquarters provides this number or enters it after you submit the form.

b. *Block 2 (DML RECON RPT NO.).* Leave blank unless a higher headquarters provides this number. Higher headquarters provides this number or enters it after you submit the form. Company SOP may specify the procedures for determining this number.

c. *Block* 3 *(DATE).* Enter the date the reconnaissance was performed.

d. *Block 4 (TIME).* Enter the time the reconnaissance party arrived at the target site (local or ZULU time).

e. *Block 5 (RECON ORDERED BY).* Enter the command authority authorizing the reconnaissance action.

f. *Block* 6 *(PARTY LEADER).* Enter the name of NCOIC or OIC of the reconnaissance party who was physically at the site when the reconnaissance was performed.

g. *Block 7 (MAP NAME, SCALE, SHEET #, and SERIES #).* Obtain this information from a map of the reconnaissance area and enter the information in this block.

h. *Block 8 (TARGET AND LOCATION).* Enter a brief description of the target and the distance and direction from an identifiable landmark (railroad bridge, crossroad, hilltop, and so forth). For example, "Target is 275 degrees, 300 meters from the railroad bridge, 2 miles east of Hanesville, on Route 2."

i. *Block 9 (TIME OBSERVED).* Enter the time you last saw the target as you departed the site.

j. *Block 10 (COORDINATES).* Enter the complete 8-digit map coordinates of the target.

k. *Block 11 (GENERAL DESCRIPTION (attach sketches)).* When applicable, include the type of construction, width of the roadway, number of lanes or tracks, type of pavement, number of spans, condition of spans or entire bridge, and bridge categorization and classification. For example,

"Prestressed-concrete T-beam bridge, four simple spans supported by six concrete columns, two lanes; total bridge length is 140 feet; roadway width is 30 feet; overall bridge width is 36 feet; height is 16 feet; Class 80; very good condition."

l. *Block 12 (NATURE OF PROPOSED DEMOLITION (attach sketches)).* State the expected amount of destruction and the priority for placing charges, if feasible. Provide a sketch showing the number and type of charges to use (tamped or untamped), where the charges should be placed, and the type of firing system required.

m. *Block 13 (UNUSUAL FEATURES OF SITE).* Include any special features of the target or site that might affect the method of demolition (high-tension lines, radar installation, underwater blasting, and so forth). Give any details that may affect the security of the target and the demolition work party.

n. *Block 14 (EXPLOSIVES REQUIRED).* Indicate the types, quantities, caps, detonators, and so forth proposed for the demolition.

o. *Block 15 (EQUIPMENT AND TRANSPORT REQUIRED).* Specify the amount and type of transportation required (for example, two 5-ton dump trucks, one ram set with 50 cartridges, two post-hole diggers, two demolition sets, 10 pounds of 16d nails, twelve 8-foot 2 by 4s). Comments may be continued on the reverse side of the form.

NOTE: Troops may not ride in vehicles transporting explosives.

p. *Block 16 (PERSONNEL AND TIME REQUIRED FOR:).* Complete subsections a and b, indicating the number of personnel and amount of time necessary for placing the demolitions. The distance between the firing points and firing systems will be a consideration for determining the amount of time necessary to arm and fire the explosives.

q. *Block 17 (TIME, LABOR, AND EQUIPMENT REQUIRED FOR BYPASS; SPECIFY LOCATION AND METHOD).* Specify the equipment necessary to clear the site after demolition and the available bypasses that allow units to bypass the site. Comments may be continued on the reverse side of the form.

r. *Block 18 (REMARKS).* Include any appropriate remarks that are not covered in Blocks 1 through 17. Comments may be continued on the reverse side of the form.

s. *Block* 19 *(ADDITIONAL COMMENTS).* Use this block as a continuation for Blocks 1 through 18. Identify the block being continued.

F-3. Instructions for Sketches. Use the following instructions and the sample form shown in Figure F-2 (pages F-38 through F-42) to complete the necessary sketches for DA Form 2203-R.

a. *General Description Sketch.* This sketch should include—

- The avenues of approach to the target and possible bypasses in the vicinity of the target. Indicate route numbers and the direction of cities or towns.
- Rivers or streams including name, direction of flow, and velocity in meters per second.
- Terrain features, including observation points, cover and concealment, swampy areas, deep valleys, and so forth.

- A compass arrow indicating north (indicate grid or magnetic).
- Dimensions of the proposed target.
- Number and length of bridge spans.
- Height of the bridge from the ground or water.

b. *Nature of Proposed Demolition Sketch.* This sketch should include-

- Dimensions of members to be cut.
- Placement of charges
- Charge calculations. Use either the formula or table method, but show your work.
- Priming of charges.
- Branch lines.
- Ring mains.
- Firing systems.
- Firing points.

Unclassified
(Security Classification)

ORDERS FOR THE DEMOLITION
(USAEREUR Reg 525-2: STANAG 2017)

INSTRUCTIONS FOR PREPARING THIS FORM

i. Paragraphs 1-9 are to be completed, placing a cross in each box where applicable.

ii. Copy No 1 is to be issued to the Demolition Guard Commander and Copy No 2 to the Firing Party Commander. Copy No 3 is retained by the Authorized Commander. If there is no Demolition Guard, Copy No 1 is issued to the unit providing the firing party.

iii. If the Demolition Guard Changes, a new form should be issued.

ORDERS TO THE DEMOLITION GUARD COMMANDER

iv. You are responsible for:

a. Command of the Demolition Guard and Demolition Firing Party.

b. The security of the demolition site from enemy attack or sabotage, and the control of traffic and refugees at the demolition site.

c. Giving the order to the Demolition Firing Party Commander in writing (para 10 of Copy No 2) to change the State of Readiness.

d. Giving the order to the Demolition Firing Party Commander in writing (para 13 of Copy No 2) to fire the demolition.

e. Keeping the Authorizing Commander informed of the operational situation at the demolition site.

v. The Demolition Firing Party Commander is in technical control of the demolition but you must ensure that he keeps you informed of all action he takes. Your command post should be co-located with the firing point if possible.

vi. You are to find out from the Demolition Firing Party Commander the time required to change the demolition from State of Readiness 1 (SAFE) to State of Readiness 2 (ARMED), pass this information to the Authorized Commander and record it in para 10a.

vii. You are to nominate a deputy forthwith and compile a seniority roster. You are to ensure that each man knows his place in the roster, understands his duties, and knows where to find this form if you become a casualty or are unavoidably absent. The seniority roster must be made known to the Demolition Firing Party Commander.

viii. Once State of Readiness 2 (ARMED) has been ordered, either you or your deputy must always be at your command post so that orders can be passed immediately to the Demolition Firing Party Commander.

ix. In the event of a misfire or only partially successful demolition, you are to give the Demolition Firing Party protection until such time as it has completed the demolition.

x. If you are ordered to hand over the demolition to another unit without the issue of a new form, para 11 is to be completed and the new form handed to the new Demolition Guard Commander. A receipt is to be issued and retained by you. If a new form has been issued, para 11 is to be completed on the old form which you will retain.

xi. When the demolition has been completed, you are to report its effectiveness to the Authorized Commander by the fastest means available, and return Copy No 1 to him with para 14 completed.

xii. If you receive orders to fire the demolitions other than those given in para 5, you should refer to the Authorized Commander.

ORDERS TO THE DEMOLITION FIRING PARTY COMMANDER

xiii. You are in technical charge of the preparation, charging, and firing of the demolition.

xiv. The Demolition Guard Commander (if one is provided) is responsible for:

a. Tactical command of all troops at the demolition site; you are therefore under his command.

b. Giving you in writing (para 10) the order to change the State of Readiness.

c. Giving you in writing (para 13) the order to fire the demolition.

xv. You are to consult with the Demolition Guard Commander over the siting of your firing point, which is to be co-located with his command post whenever practicable. It should be within sight of the target.

xvi. You are to nominate a deputy forthwith, and compile a seniority roster. You are to ensure that each man knows his place in the roster, understands his duties, and knows where to find this form if you become a casualty or are unavoidably absent. The seniority roster is to be made known to the Demolition Guard Commander.

xvii. You are to complete para 10e of the form and to report this information to the Demolition Guard Commander, if provided, otherwise to the Authorized Commander.

xviii. Once State of Readiness 2 (ARMED) has been ordered, either you or your deputy must remain at the Firing Point.

xix. When there is no Demolition Guard and you receive orders to fire the demolition other than those given in para 5, you should refer to the Authorized Commander or to your immediate superior.

xx. If you are ordered to hand over the demolition to another unit without the issue of a new form, para 11 is to be completed and the form handed to the new Demolition Firing Party Commander. A receipt is to be issued and retained by you. If a new form has been issued, para 11 is to be completed on the old form, which you will retain.

xxi. When the demolition has been completed, you are to report its effectiveness to your Unit Commander by the fastest means available, and return Copy No 2 to him with para 14 completed. If there is no Demolition Guard, the Unit Commander must pass the results and the completed Copy No 1 to the Authorized Commander. If mines are laid, they are to be reported and recorded on a minefield record (STANAG 2036).

Unclassified
(Security Classification)

SAMPLE

Figure F-1. Sample target folder

Unclassified
(Security Classification)

COPY NO 2 OF 3

DEMOLITION ORDER
SERIAL NO 004

From John P. Smith, Gen. USA
X Corps Commanding
(Authorized Commander)

1. Demolition Guard Commander
2. Demolition Firing Party Commander
3. Retained by the Authorized Commander
4. .....

PART I

1. Demolition Target Details:

a. Description Concrete Arch Bridge .....
b. Location (grid coordinates) WM 3172 9326 .....
c. Target nickname, number, or code
(All orders are to be prefixed by target identifying nickname, number, or code.)
d. Technical instructions .....
.....

2. Executing Units:

a. Demolition Guard .....
b. Demolition Firing Party .....

3. Orders to the Demolition Firing Party Commander

a. The demolition target is to be prepared to State of Readiness 1 ..... by 271500 (DTG).
b. ☒ All other orders will be issued to you by the Demolition Guard Commander. Record their receipt in Part II.
c. ☐ There is no Demolition Guard. You are to act as instructed in para 5, 6, and 7, recording the orders received in Part II.
(Only one box is to be crossed)

4. Orders to the Demolition Guard Commander

Your responsibilities are detailed in Part IV. You are to act as instructed in para 5, 6, and 7, recording the orders received in Part II.

5. Demolition is to be fired

a. ☐ Immediately upon being prepared.
b. ☒ Upon receipt of code in para 8c by radio.
c. ☐ Upon receipt of the order from the Authorized Commander or his Liaison Officer personally.
d. ☐ (Other orders) .....

6. Emergency Firing Orders

a. ☒ You will NOT fire the demolition except as ordered in para 5.
b. ☐ You WILL fire the demolition on your own initiative if the enemy is in the act of capturing it.
(Only one box is to be crossed)

7. Orders other than for firing will be given:

a. ☐ By the Authorized Commander personally.
b. ☐ By the Authorized Commander's Liaison Officer personally.
c. ☒ By radio.
d. ☐ ..... (other means)

SAMPLE

Unclassified
(Security Classification)
2

Figure F-1. Sample target folder (continued)

Unclassified
(Security Classification)

8. Code

Action to be taken	Code
a. Change from State 1 (SAFE) to State 2 (ARMED)	Brad
b. Change from State 2 (ARMED) to State 1 (SAFE)	Bill
c. Fire the demolition now	Dick
d. Para 3b cancelled, para 3c applies	Bruce
e. Para 3c cancelled, para 3b applies	
f. Para 5c cancelled, para 5b applies	
g. The Authorized Commander is changed to	
h. [illegible]	[illegible]
i. [illegible]	[illegible]

9. Authorized Commander

Signature [illegible] Rank/Name [illegible]

Appointment [illegible] Date/Time Group [illegible]

PART II

10. Changing State of Readiness:

a. Time estimated by Firing Party Commander to change from State of Readiness I (SAFE) to State of Readiness 2 (ARMED) is ..... minutes.

b.

State of Readiness Ordered	Originator	Date/Time Group of:	
		Receipt of Order	Change Completed

11. Handover and Takeover of Demolition Target:

	Rank, Name, and Unit	Signature	Date/Time Group
Transferring Commander			
Accepting Commander			

Unclassified
(Security Classification)

3

SAMPLE

Figure F-1. Sample target folder (continued)

Unclassified
(Security Classification)

12. Record of Other Changes to Part I (if any)

Detail	Date/Time of Receipt

13. FIRE THE DEMOLITION NOW

Signed .....
(Rank, name, unit) .....
(Date/Time Group) .....
(or enter date/time group of receipt of code in para 8c)

PART II

14. Demolition Report

a. Bridge
Estimated width of gap ..... b. Road/Runway/Railway
No of spans down ..... No. of craters .....
c. Other target ..... Diameter/Depth .....
d. Mines laid: AT mines ..... AP mines .....

Sketch

Signature ..... Rank/Name/Unit .....

Unclassified
(Security Classification)
4

SAMPLE

Figure F-1. Sample target folder (continued)

Annex/annexe 'A' (DofA) (MdeA) to/au STANAG 2123
Anhang 'A' (DofA) zum STANAG Nr. 2123

NATO-CONFIDENTIAL on completion OTAN-CONFIDENTIEL une fois remplie VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN nach Ausfüllen	+NATO-RESTRICTED +DIFFUSION RESTREINTE +VS-NUR FÜR DEN DIENST-GEBRAUCH ab Alarmmaßnahme

OBSTACLE FOLDER
CARNET D'OBSTACLE
SPERRHEFT

Type of obstacle	Concrete Arch Bridge
Type d'obstacle	
Art der Sperre	

SAMPLE

CLASS	CATEGORIE	DRINGLICHKEIT	
1.++PRELIMINARY 2.++~~RESERVED~~	1.++Préliminaire 2.++DE MANOEUVRE (1) RESERVE (1)	1.++Sofort-Maßnahme 2.++Reserviert	

Serial number 004	Target no.
Numero d'ordre	Dispositif No.
Laufende Nummer	Objektnummer

Copy	Exemplaire	Ausfertigung	
2	No.		

NOTE Anmerkung

\+ When blank
Si laisse en blanc
Wenn unausgefüllt

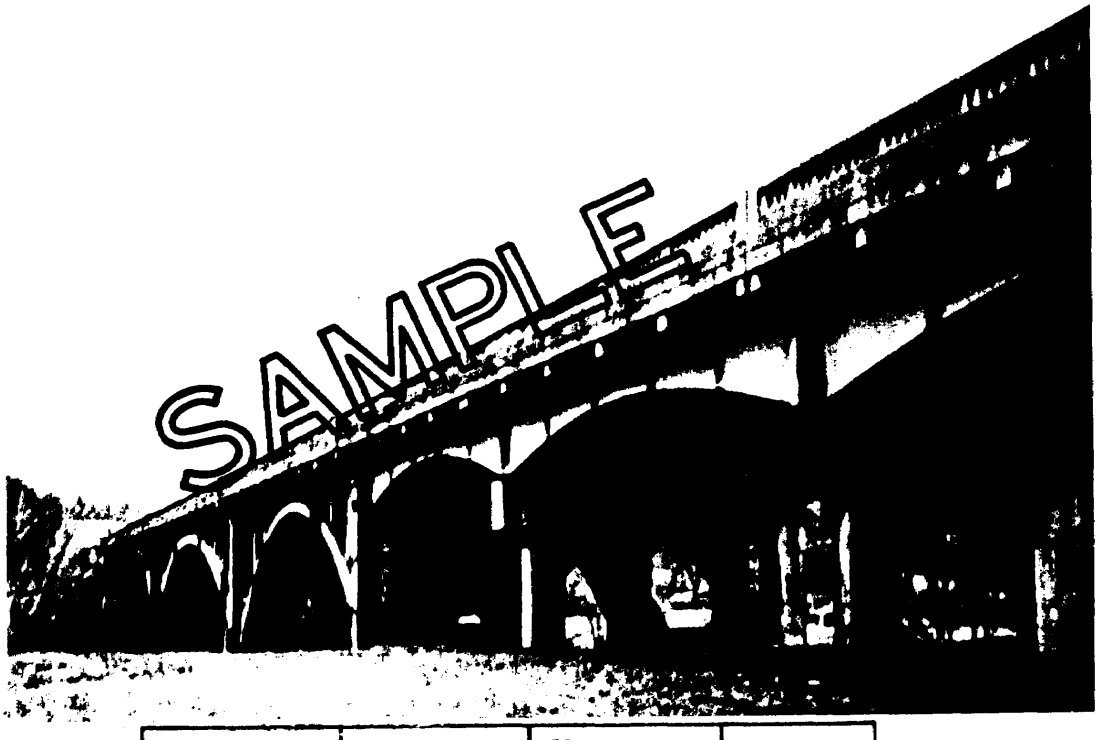
++ Strike out item not applicable
Rayer la mention inutile
Nicht zutreffendes streichen

(1) Delete the term NOT used
Barrer la mention NON utilisée

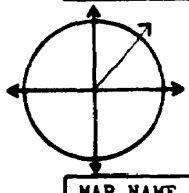
Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(1) PHOTOGRAPH OF TARGET — PHOTOGRAPHIE DE L'OUVRAGE — FOTOGRAPHIE DES SPERROBJEKTS



DESCRIPTION	DESCRIPTION	BESCHREIBUNG	



Indicate direction of view — Indiquer direction de prise de vue — Richtung, in der das Objekt gesehen wurde, einzuzeichnen

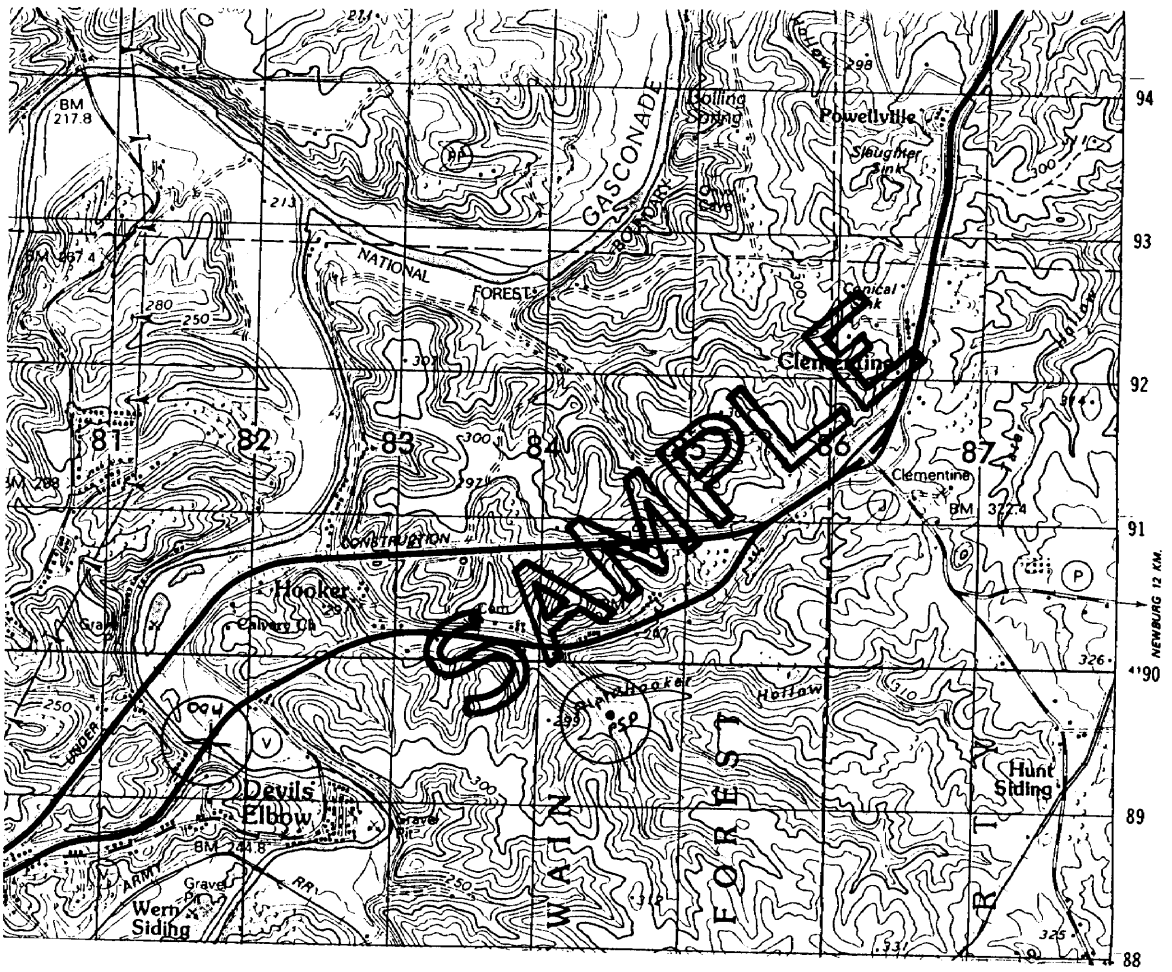
MAP NAME AND SCALE	NOM ET ÉCHELLE DE LA CARTE	KARTENBEZEICHNUNG UND MASS-STAB
Waynesville	1:50,000	

GRID REFERENCE OF TARGET	COORDONNEES DU DISPOSITIF	KOORDINATEN DES OBJEKTS
WM 8170 8935		

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(a) LOCATION OF TARGET AND PRESTOCK POINT.	EMPLACEMENTS DU DISPOSITIF ET DU CENTRE DE RATTACHEMENT (PRESTOCKAGE).	LAGE DES OBJEKTS UND MUNITIONSLAGERPLATZ.



SCALE	ÉCHELLE	Maßstab	1: ~~250.000~~

Figure F-1. Sample target folder (continued)

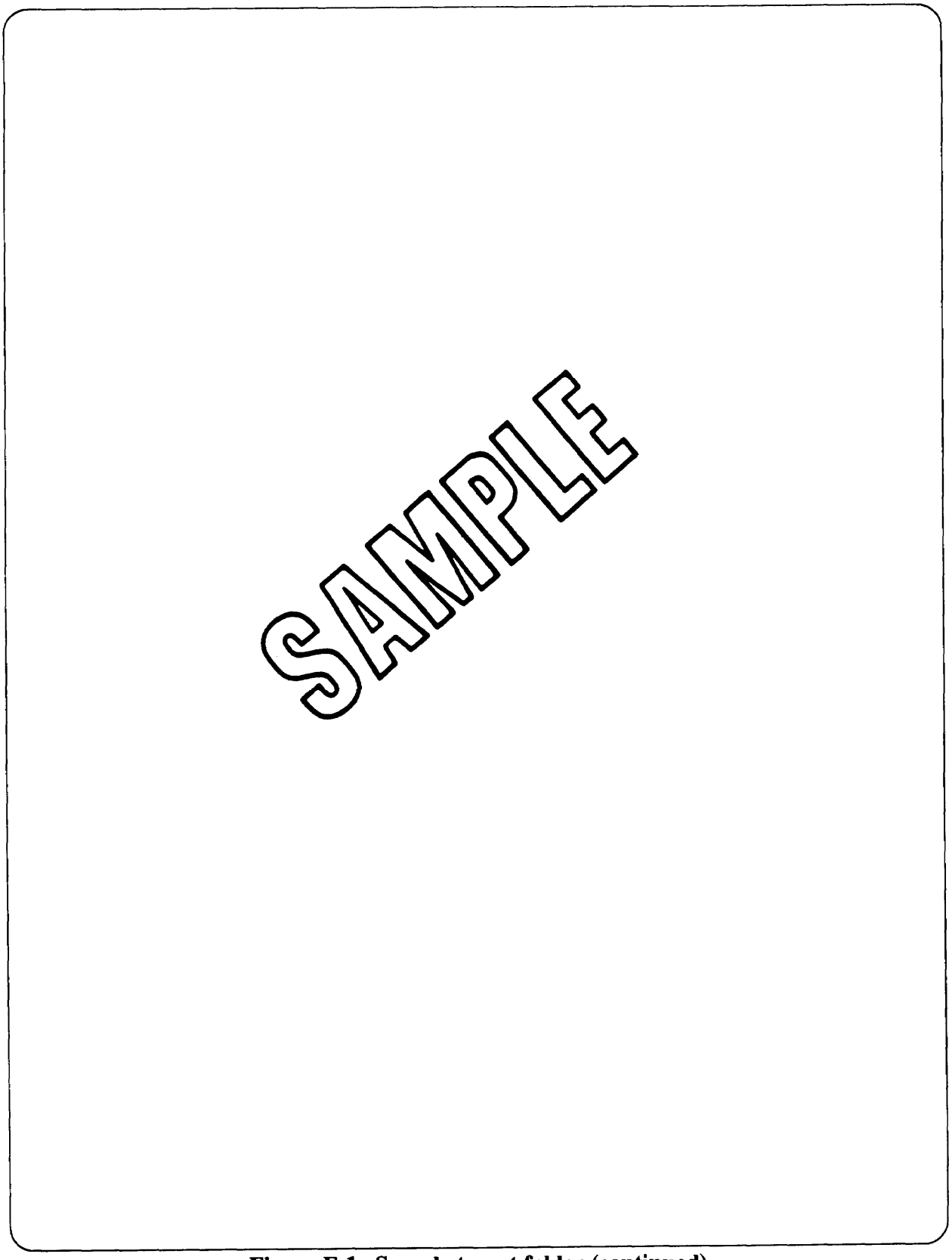
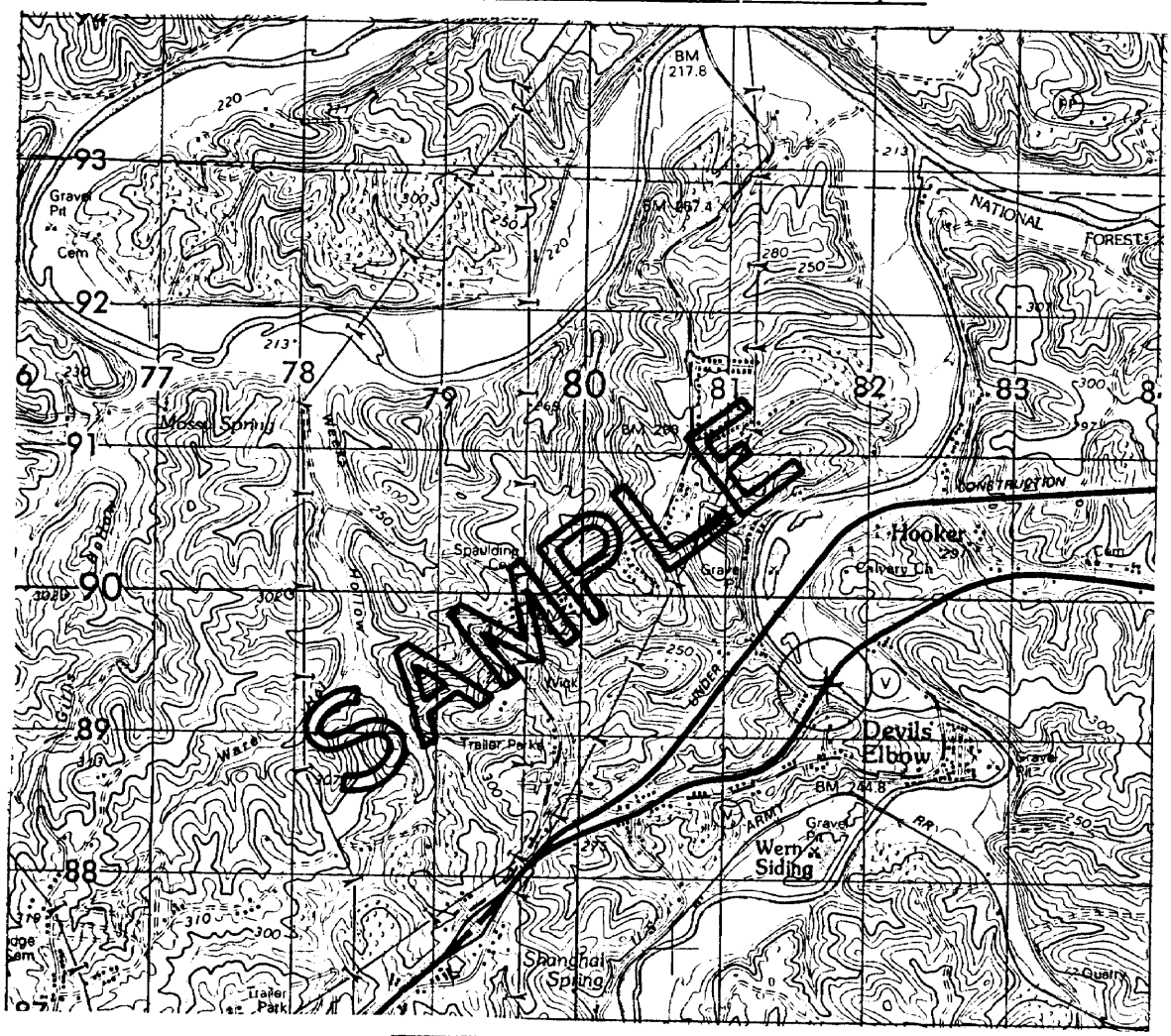


Figure F-1. Sample target folder (continued)

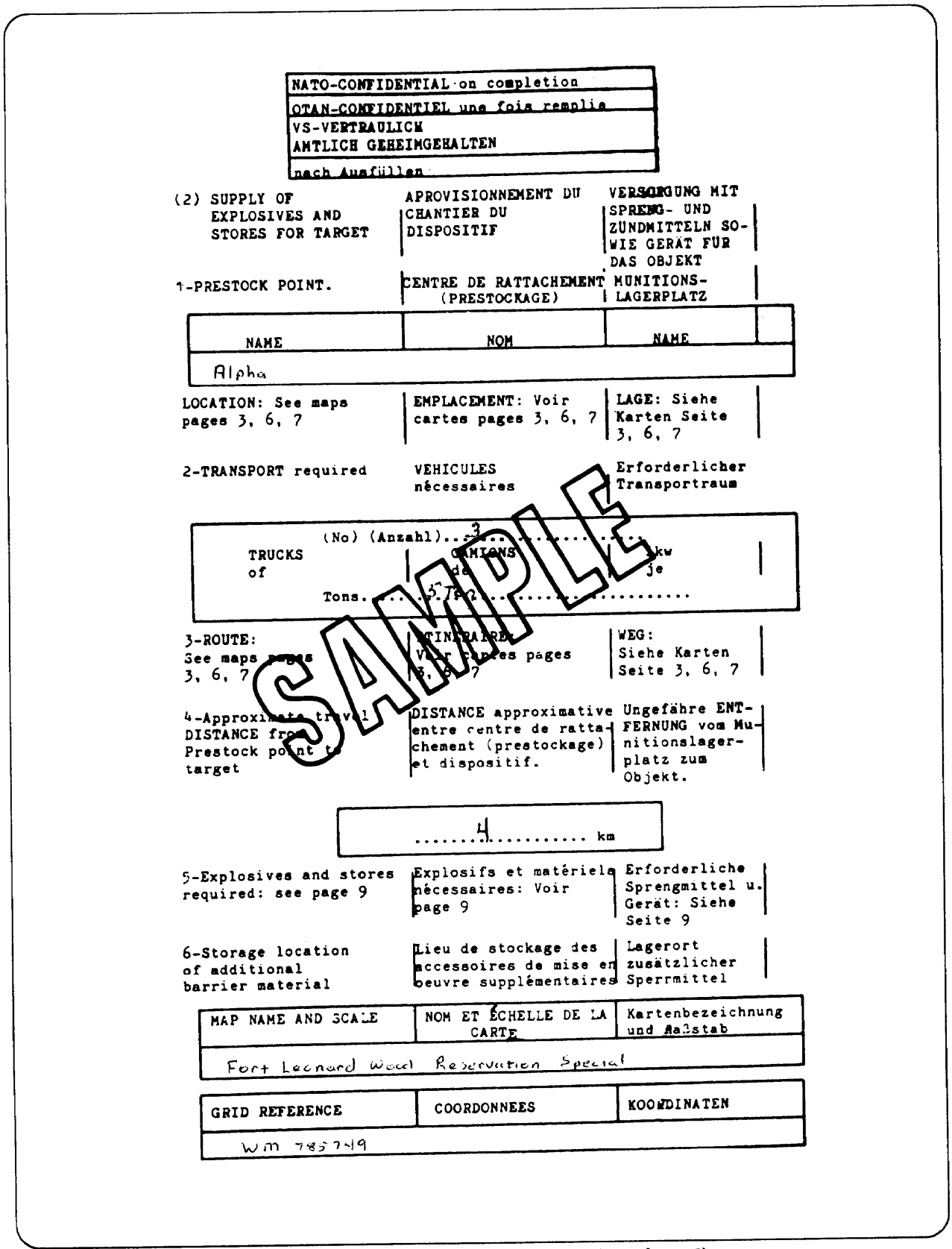
NATO-CONFIDENTIAL on completions
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(1b) LOCATION OF TARGET	EMPLACEMENT DU DISPOSITIF	LAGE DES OBJEKTS



SCALE	ÉCHELLE	Maßstab	1:50.000

Figure F-1. Sample target folder (continued)



NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(2) SUPPLY OF EXPLOSIVES AND STORES FOR TARGET	APROVISIONNEMENT DU CHANTIER DU DISPOSITIF	VERSORGUNG MIT SPRENG- UND ZÜNDMITTELN SOWIE GERÄT FÜR DAS OBJEKT
1-PRESTOCK POINT.	CENTRE DE RATTACHEMENT (PRESTOCKAGE)	MUNITIONS-LAGERPLATZ

NAME	NOM	NAME
Alpha		

LOCATION: See maps pages 3, 6, 7	EMPLACEMENT: Voir cartes pages 3, 6, 7	LAGE: Siehe Karten Seite 3, 6, 7

2-TRANSPORT required — VEHICULES nécessaires — Erforderlicher Transportraum

TRUCKS of	(No) (Anzahl)...3... CAMIONS de	...kw ...je
	Tons...5 Tn...	

3-ROUTE: See maps pages 3, 6, 7	ITINERAIRE Voir cartes pages 3, 6, 7	WEG: Siehe Karten Seite 3, 6, 7

4-Approximate travel DISTANCE from Prestock point to target	DISTANCE approximative entre centre de rattachement (prestockage) et dispositif.	Ungefähre ENTFERNUNG vom Munitionslagerplatz zum Objekt.
	...4... km	

5-Explosives and stores required: see page 9	Explosifs et matériels nécessaires: Voir page 9	Erforderliche Sprengmittel u. Gerät: Siehe Seite 9
6-Storage location of additional barrier material	Lieu de stockage des accessoires de mise en oeuvre supplémentaires	Lagerort zusätzlicher Sperrmittel

MAP NAME AND SCALE	NOM ET ÉCHELLE DE LA CARTE	Kartenbezeichnung und Maßstab
Fort Leonard Wood Reservation Special		

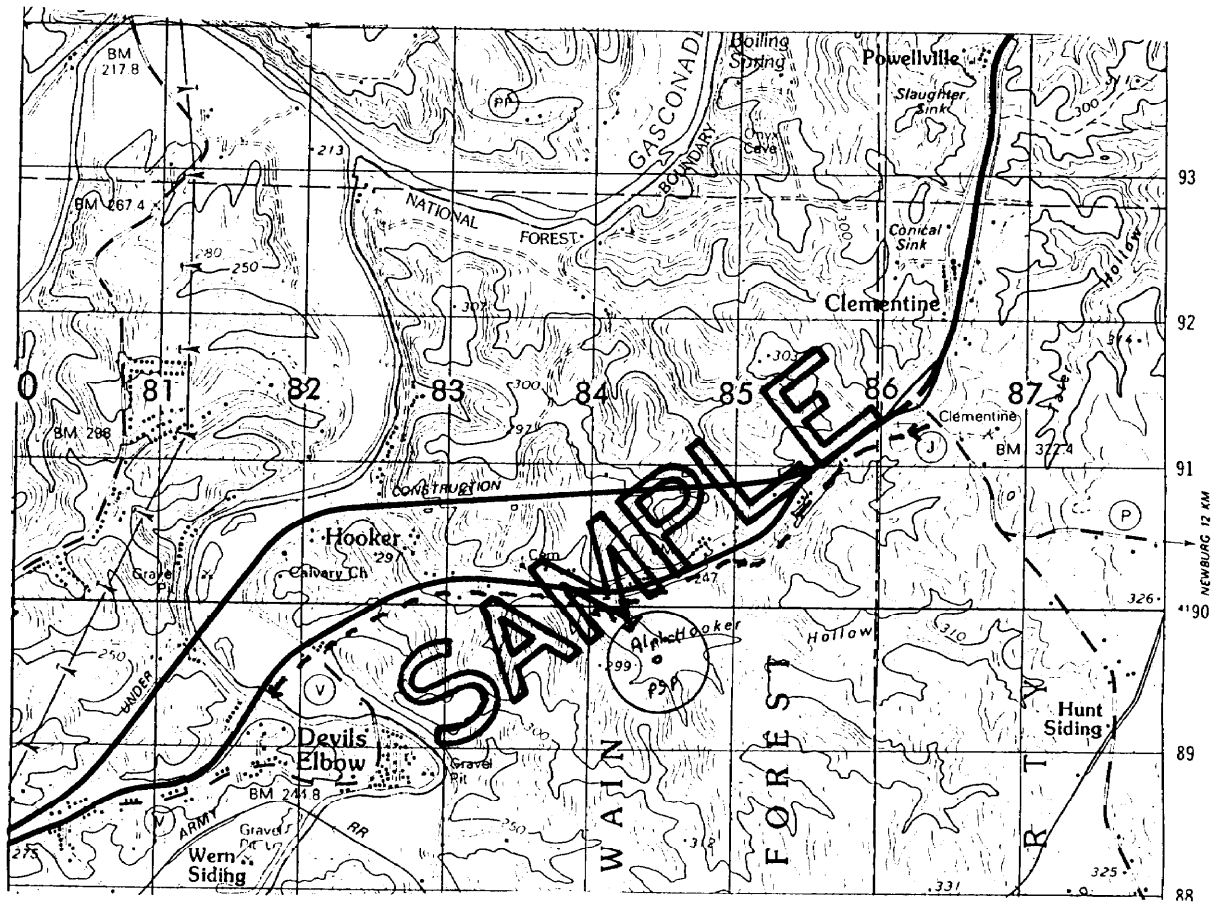
GRID REFERENCE	COORDONNEES	KOORDINATEN
WM 785749		

SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(2a) LOCATION OF PRESTOCK POINT	EMPLACEMENT DU DÉPÔT DE MUNITION	LAGE DES MUNITIONS-LAGERPLATZES



		Maßstab	1:50.000

Figure F-1. Sample target folder (continued)

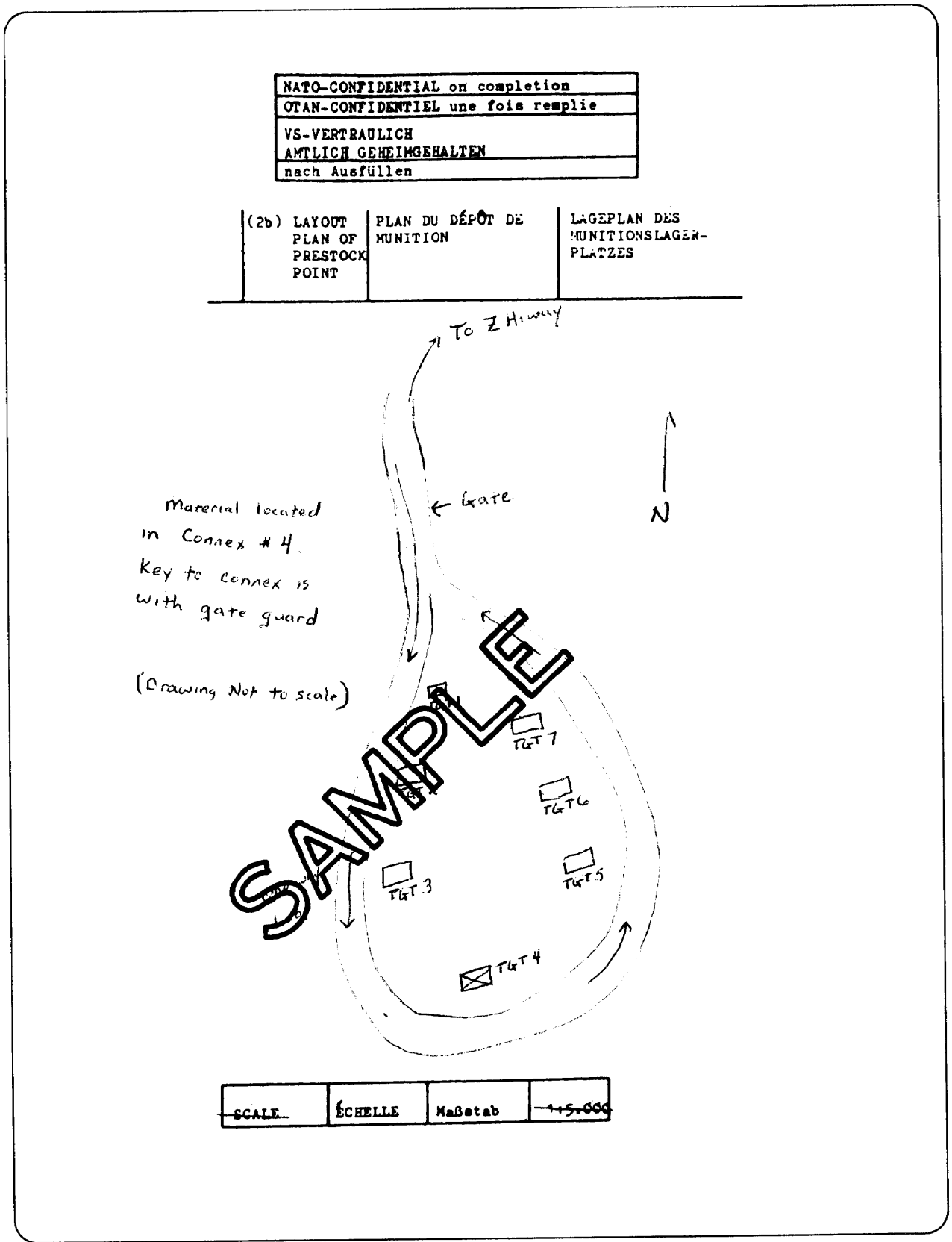


Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(2c)

Instructions for opening ammunition storage vault door
Directives pour l'ouverture de la porte du dépôt de munitions
Anweisung für das Öffnen der Sperrmittelhaustür

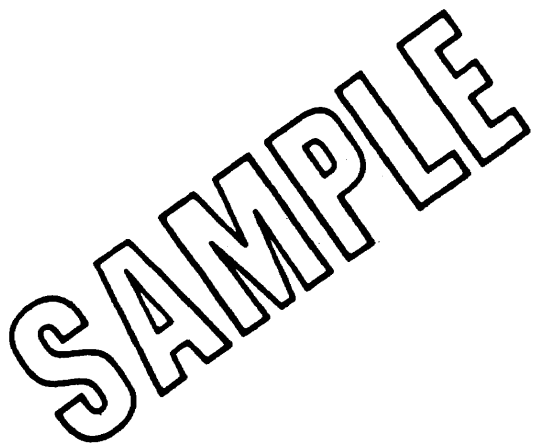


Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

2c)

Instructions for opening ammunition storage vault door
Directives pour l'ouverture de la porte du dépôt de munitions
Anweisung für das Öffnen der Sperrmittelhaustür

SAMPLE

Figure F-1. Sample target folder (continued)

Key for ammunition storage facility
Clefs pour la soute de munitions
Schlüssel für das Munitionslagerhaus

The bearer of this document is authorised to enter the ammunition site and to pick up from Bunker No. 4 the barrier material for Target No. 004.
Le titulaire du présent document est habilité à accéder au lieu de stockage des munitions et à prendre - dans la soute no. .... - les accessoires nécessaires à la mise en oeuvre de l'obstacle no. .... .
Der Inhaber dieses Dokuments ist berechtigt den Sperrmittellagerort zu betreten und aus dem Bunker Nr. .... das Sperrmaterial für die Sperre Nr. .... zu entnehmen.

SAMPLE

If the keys are not kept in this obstacle folder their location is to be marked clearly here: Keys are kept by gate guard at PSP Alpha
Si les clés ne seront pas conservées dans le présent carnet d'obstacles, indiquer ci-après l'endroit de conservation exact:
Werden die Schlüssel nicht in diesem Sperrheft aufbewahrt ist der genaue Ort hier anzugeben:

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completation
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN nach Ausfüllen

(2d) EXPLOSIVES, STORES MINES REQUIRED | EXPLOSIFS, MATERIELS MINES NECESSAIRES | BEDARF AN SPRENG- UND ZÜNDMITTELN GERÄT, MINEN

TARGET No	DISPOSITIF No	OBJEKT No	
ØØ4			

PRESTOCK POINT	DEPOT DU MUNITION	MUNITIONS-LAGERPLATZ	
Alpha			

	ITEM (English)	DESIGNATION (Francais)	ART (Deutsch)	MENGE AMOUNT QUANITÉ	GESAMTGEWICHT TOTAL WEIGHT POIDS TOTAL
(1)	(2)	(3)	(4)	(5)	(6) (kg)
1	EXPLOSIVES	EXPLOSIFS	SPRENGMITTEL		
a	Cratering charges	Expl. progressifs	Trichter-sprengladungen		
b	High TNT explosives	Expl. brisants	Hochbrisanzsprengmittel	1336	1336 lbs
c	Plastic C-4 explosives	Plastique	Sprengmasse Formbar	489 PKG	610 lbs
d	Shaped charges	Charges creuses	Hohlladungen		
e	Cutting charges	Charges coupantes	Schneid-ladungen		
2	ACCESSOIRES ARTIFICES		ZÜNDMITTEL		
a	Safety Fuze	Mèche lente	Anzündschnur	100 FT	2 lbs
b	Detonating cord	Cordeau détonant	Sprengschnur	4,000 FT	88 lbs
c	Non electric Detonators	détonateurs pyro technique	Sprengkapseln	10 EA	
d	Electric Detonators	détonateurs electrique	Sprengkapseln elektrisch		
e	Prime cap	Détonateur d'amorce	Sprengkapsel-zünder		
f	Booster cap	Renforcateur	Sprengschnur-kapsel		
g	Blasting machine (exploder)	Exploseur	Zünd-maschine		
h	Cable electric (2 wire)	Cable electrique (2 file)	Zündkabel (zweiadrig)		

Fuse Igniter M-60 10 EA

SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(1)	(2)	(3)	(4)	(5)	(6)
3	TOOLE	OUTILLAGE	WERKZEUG		
a	Quarrying bars	Barres a mine	Brech-stangen		
b	Shovels	Pelles	Schaufeln		
c	Picks	Pioches	Kreuzhacken		
d	Saws Cross Cut	Scies	Sägen	3	3 lbs
	Hammer			3	4 lbs
4	STORES	MATERIEL	GERÄT		
a	Nails 10d	Pointes	Nägel	4 lbs	4 lbs
b	Wire	Fil de Fer	Draht		
c	Timber 2x12x10	Planches	Bohlen	100'	160 lbs
	Rope ½ nylon			300'	100 lbs
5	MINES	MINES	MINEN		
a	Mines AP	Mines AP	SchAbwMi		
b	Mines AT	Mines AC	PzAbwMi		
c	Fuzes	Allumeurs	Zünder(Minen)		
	TOTAL WEIGHT	POIDS TOTAL	GESAMTGEWICHT		2307

SAMPLE

Figure F-1. Sample target folder (continued)

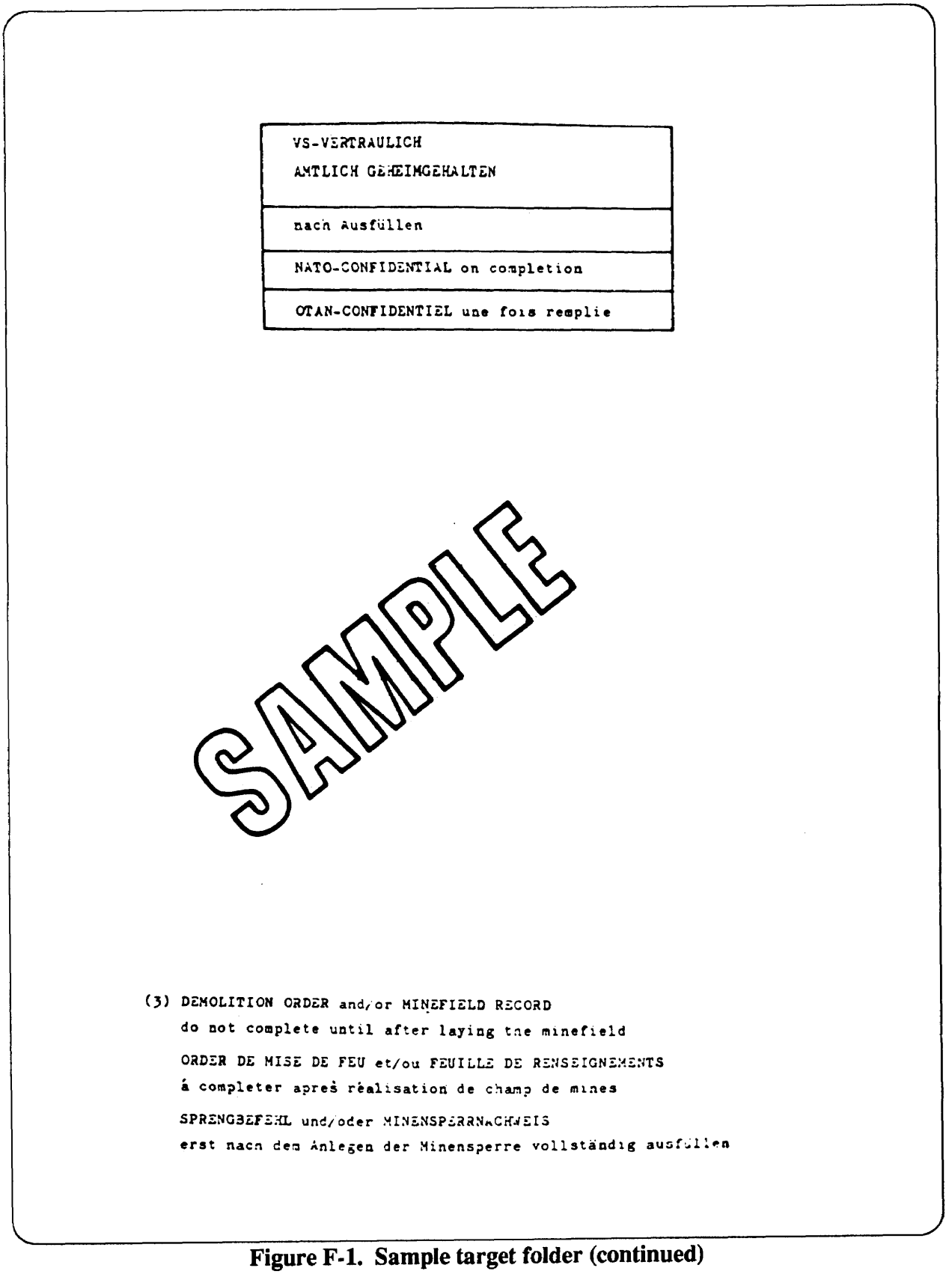

VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen
NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
SAMPLE
(3) DEMOLITION ORDER and/or MINEFIELD RECORD
do not complete until after laying the minefield
ORDER DE MISE DE FEU et/ou FEUILLE DE RENSEIGNEMENTS
á completer apres réalisation de champ de mines
SPRENGBEFEHL und/oder MINENSPERRNACHWEIS
erst nach dem Anlegen der Minensperre vollständig ausfüllen

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTREULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(3a) SPECIAL TECHNICAL INSTRUCTIONS	CONSIGNES TECHNIQUES PARTICULIERES	TECHNISCHE EINZELANWEISUNGEN

1. Time required for preparing and charging — Temps nécessaire pour préparation chargement — Zeitbedarf für die Vorbereitung zur Sprengung

Hours	Heures	Std	Min
2			

2. Time required for passing from state of readiness 1 (SAFE) to 2 (ARMED) — Temps nécessaire pour passer de l'état de préparation 1 (NON AMORCE) à 2 (AMORCE) — Zeitbedarf für Änderung der Zündbereitschaft von 1 (GESICHERT) in 2 (ENTSICHERT)

Min
30

3. Personnel required for preparing and charging — Personnel nécessaire pour préparation et chargement — Personalbedarf für die Vorbereitung zur Sprengung

N.C.O.	S/Officier	Uffz	.....5.....
Men	Hommes	Mannsch.	.....24.....

4. Personnel required for firing — Personnel nécessaire pour mise de feu — Personalbedarf für Zündtrupp

N.C.O.	S/Officier	Uffz	.....1.....
Men	Hommes	Mannsch.	.....2.....

5. Organization of work (attached if necessary) — Organisation du chantier (si nécessaire) — Arbeitsplan (falls erforderlich)

6. Drawings and sketches See page 13, 14 — Plans et croquis Voir pages 13, 14 — Zeichnungen und Skizzen Siehe Seite 13, 14

SAMPLE

Figure F-1. Sample target folder (continued)

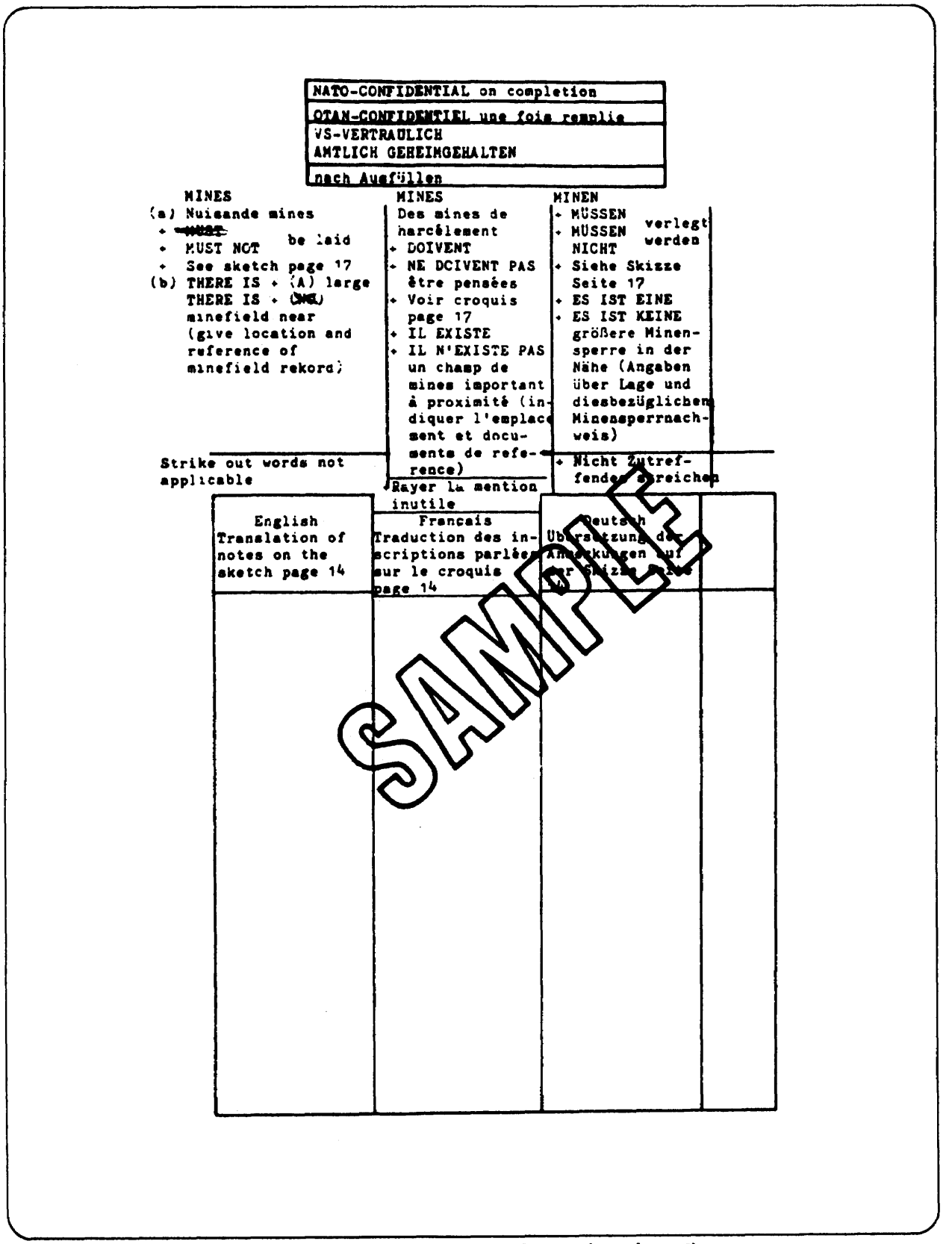
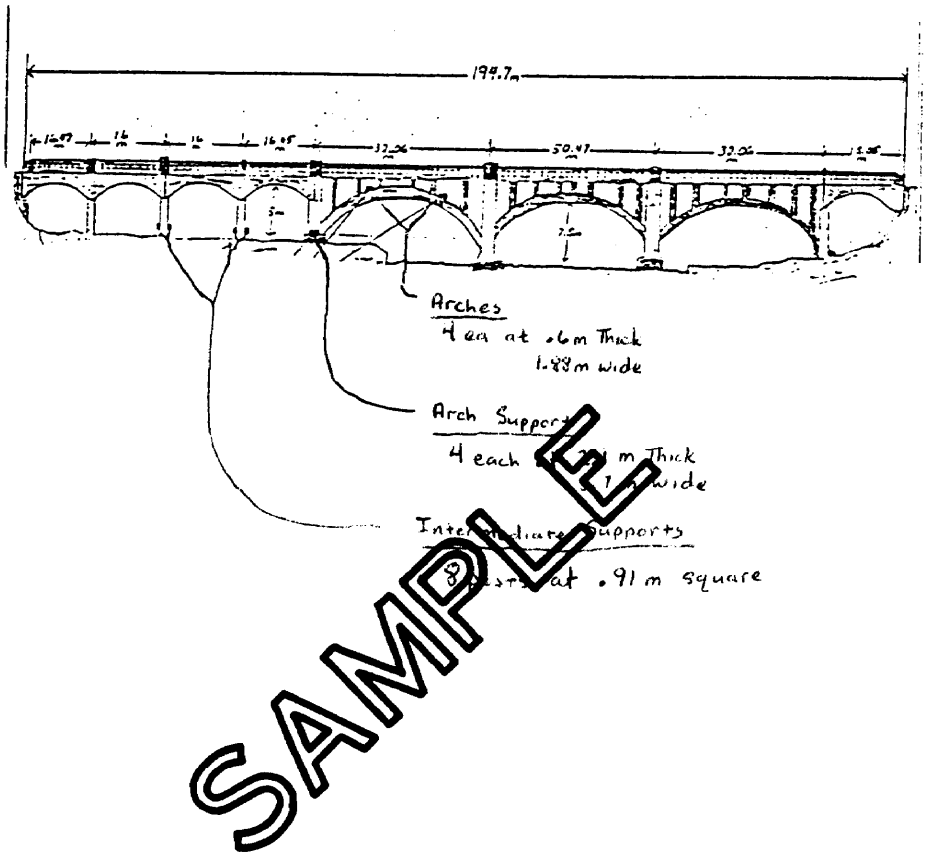

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen
MINES
(a) Nuisance mines
+ MUST
+ MUST NOT be laid
+ See sketch page 17
(b) THERE IS + (A) large
THERE IS + (NO)
minefield near
(give location and
reference of
minefield rekord)
MINES
Des mines de harcèlement
+ DOIVENT
+ NE DOIVENT PAS être pensées
+ Voir croquis page 17
+ IL EXISTE
+ IL N'EXISTE PAS un champ de mines important à proximité (indiquer l'emplacement et documents de reference)
MINEN
+ MÜSSEN
+ MÜSSEN NICHT verlegt werden
+ Siehe Skizze Seite 17
+ ES IST EINE
+ ES IST KEINE größere Minensperre in der Nähe (Angaben über Lage und diesbezüglichen Minensperrnachweis)
Strike out words not applicable
Rayer la mention inutile
+ Nicht Zutreffendes streichen
English
Translation of notes on the sketch page 14
Francais
Traduction des inscriptions parlées sur le croquis page 14
Deutsch
Übersetzung der Anmerkungen auf der Skizze Seite 14
SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(3b) SKETCH OF TARGET	CROQUIS DE L'OUVRAGE	TRENN-SCHNITT-SKIZZE



SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

English Translation of notes on the sketch page 15	Francais Traduction des inscriptions portées sur le croquis page 15	Deutsch Übersetzung der Anmerkungen auf der Skizze Seite 15	

SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(3c) SKETCH OF CHARGES	CROQUIS DE CHARGEMENT	LADUNGS-SKIZZE

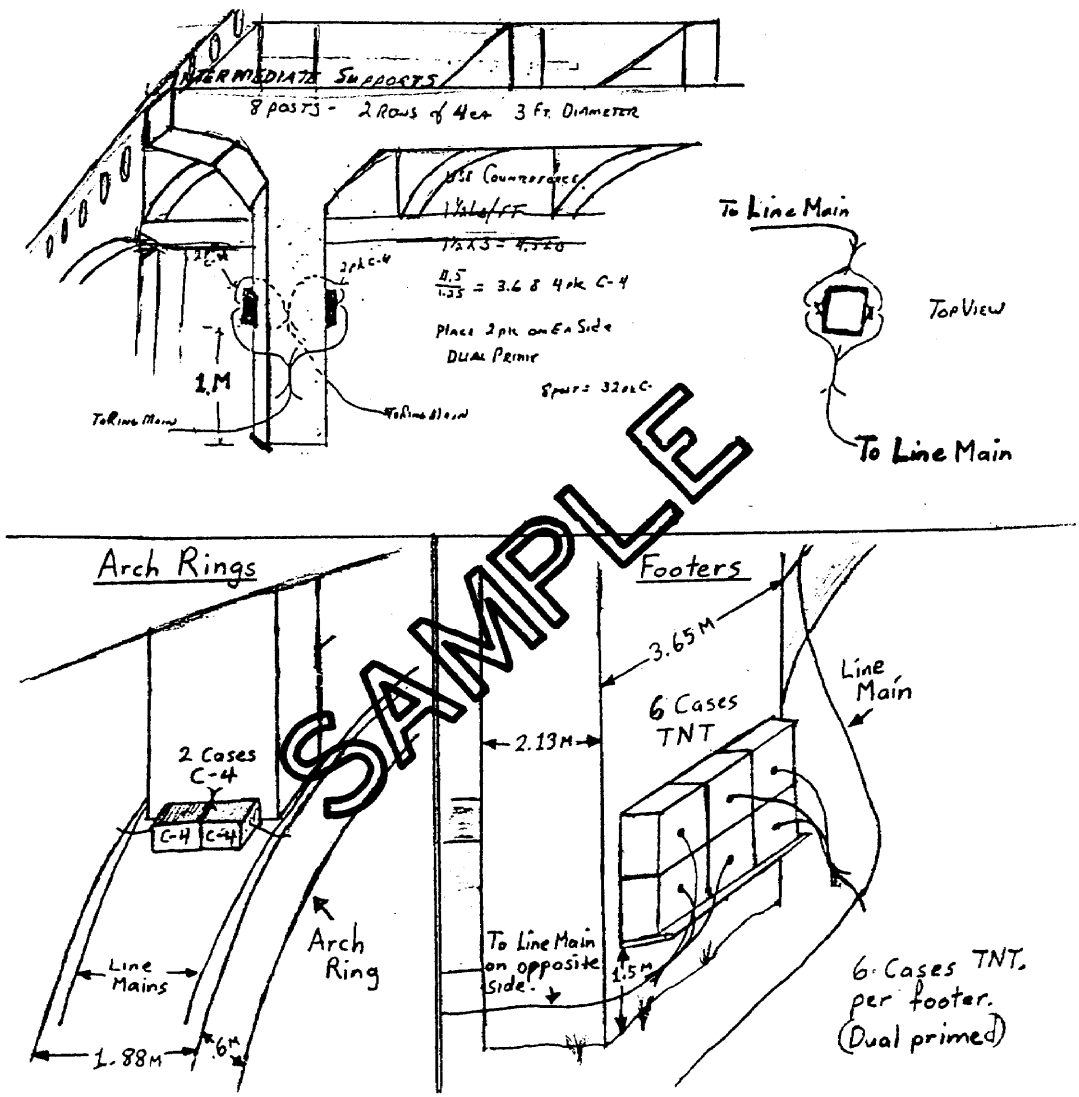


Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

English Translation of notes on the sketch page 16	Francais Traduction des inscriptions portées sur le croquis page 16	Deutsch Übersetzung der Anmerkungen auf der Skizze Seite 16	

SAMPLE

Figure F-1. Sample target folder (continued)

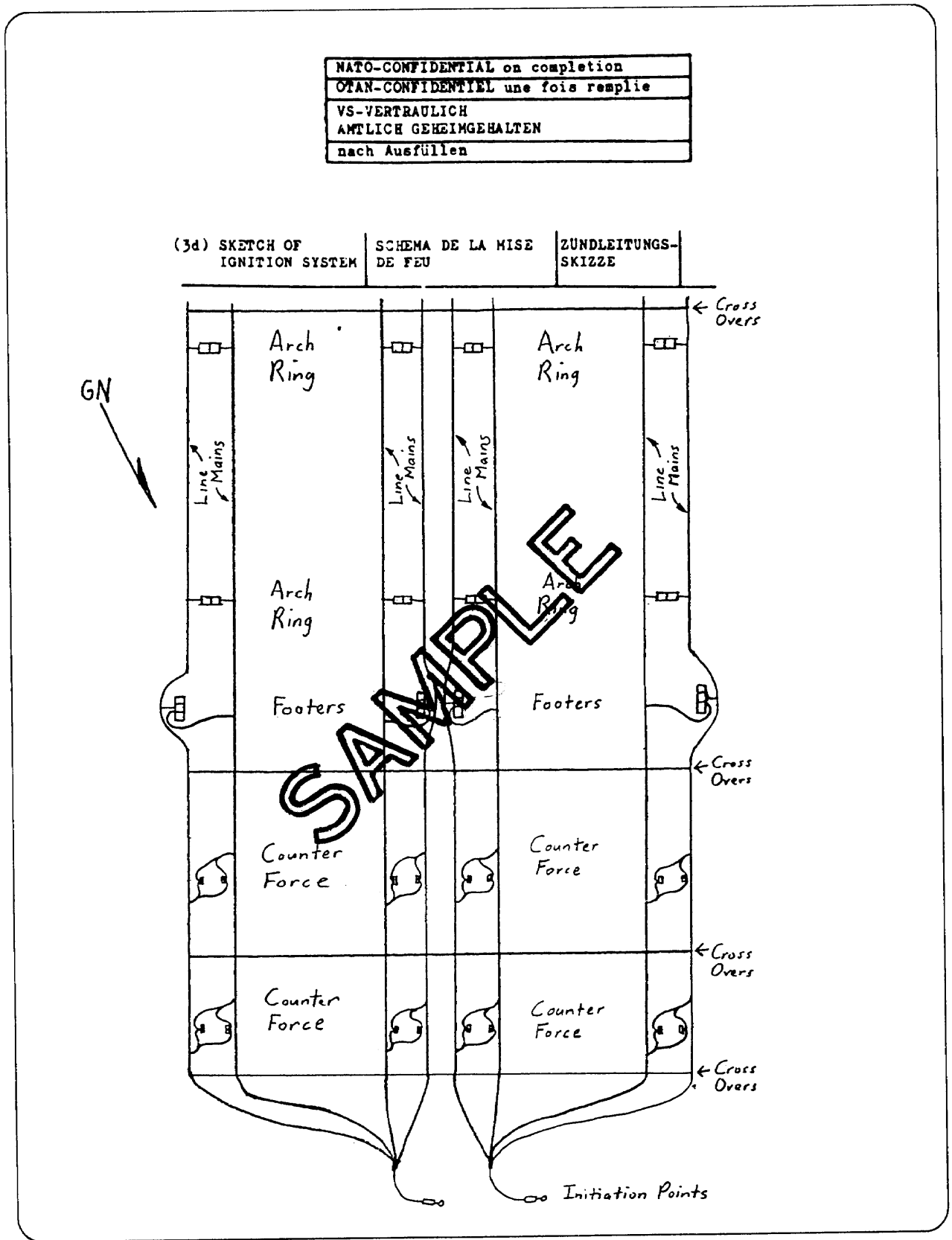


Figure F-1. Sample target folder (continued)

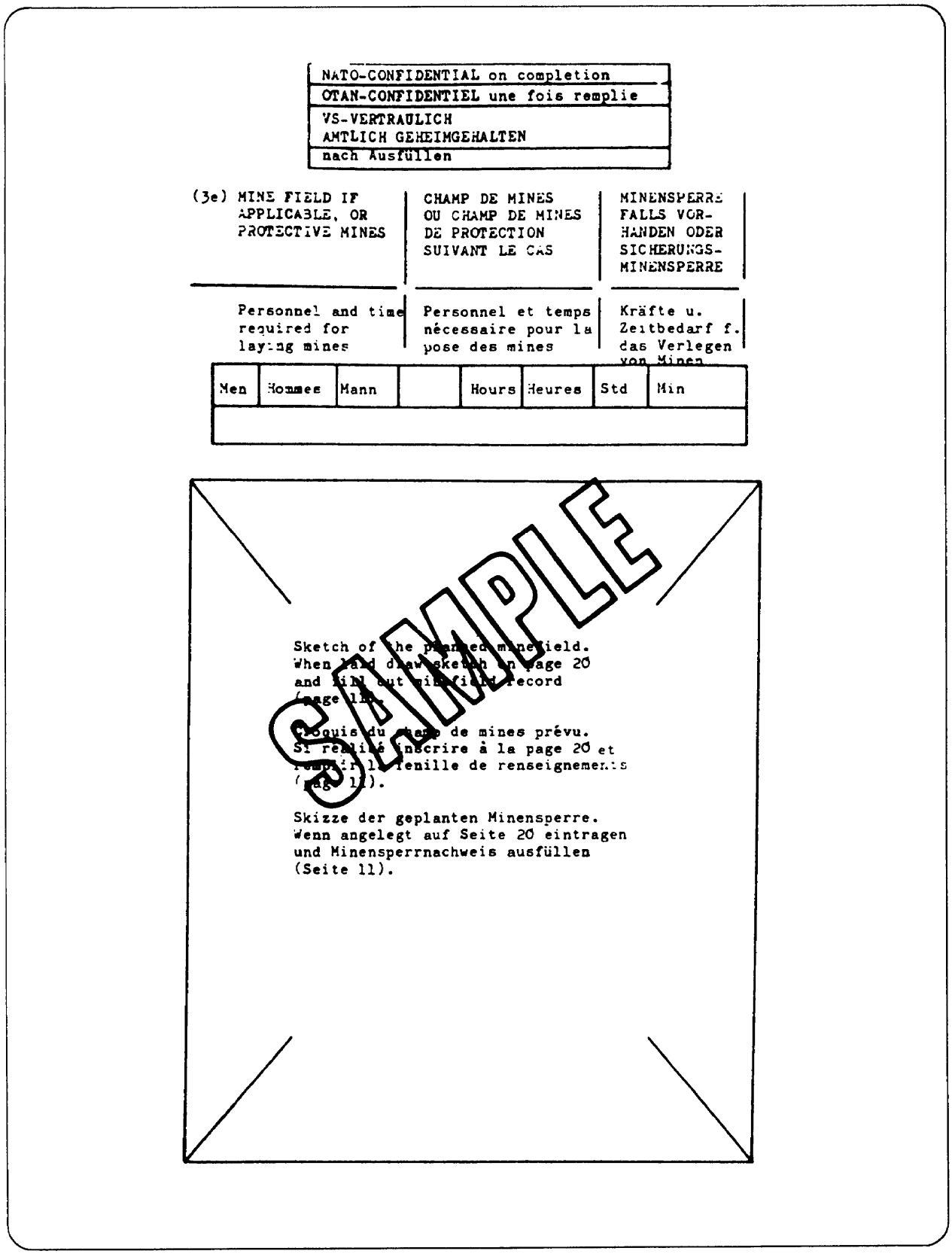

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen
(3e) MINE FIELD IF APPLICABLE, OR PROTECTIVE MINES
CHAMP DE MINES OU CHAMP DE MINES DE PROTECTION SUIVANT LE CAS
MINENSPERRE FALLS VORHANDEN ODER SICHERUNGS-MINENSPERRE
Personnel and time required for laying mines
Personnel et temps nécessaire pour la pose des mines
Kräfte u. Zeitbedarf f. das Verlegen von Minen
Men
Hommes
Mann
Hours
Heures
Std
Min
SAMPLE
Sketch of the planned minefield.
When laid draw sketch on page 20
and fill out minefield record
(page 11).
Croquis du champ de mines prévu.
Si réalisé inscrire à la page 20 et
remplir la fenille de renseignements
(page 11).
Skizze der geplanten Minensperre.
Wenn angelegt auf Seite 20 eintragen
und Minensperrnachweis ausfüllen
(Seite 11).

Figure F-1. Sample target folder (continued)

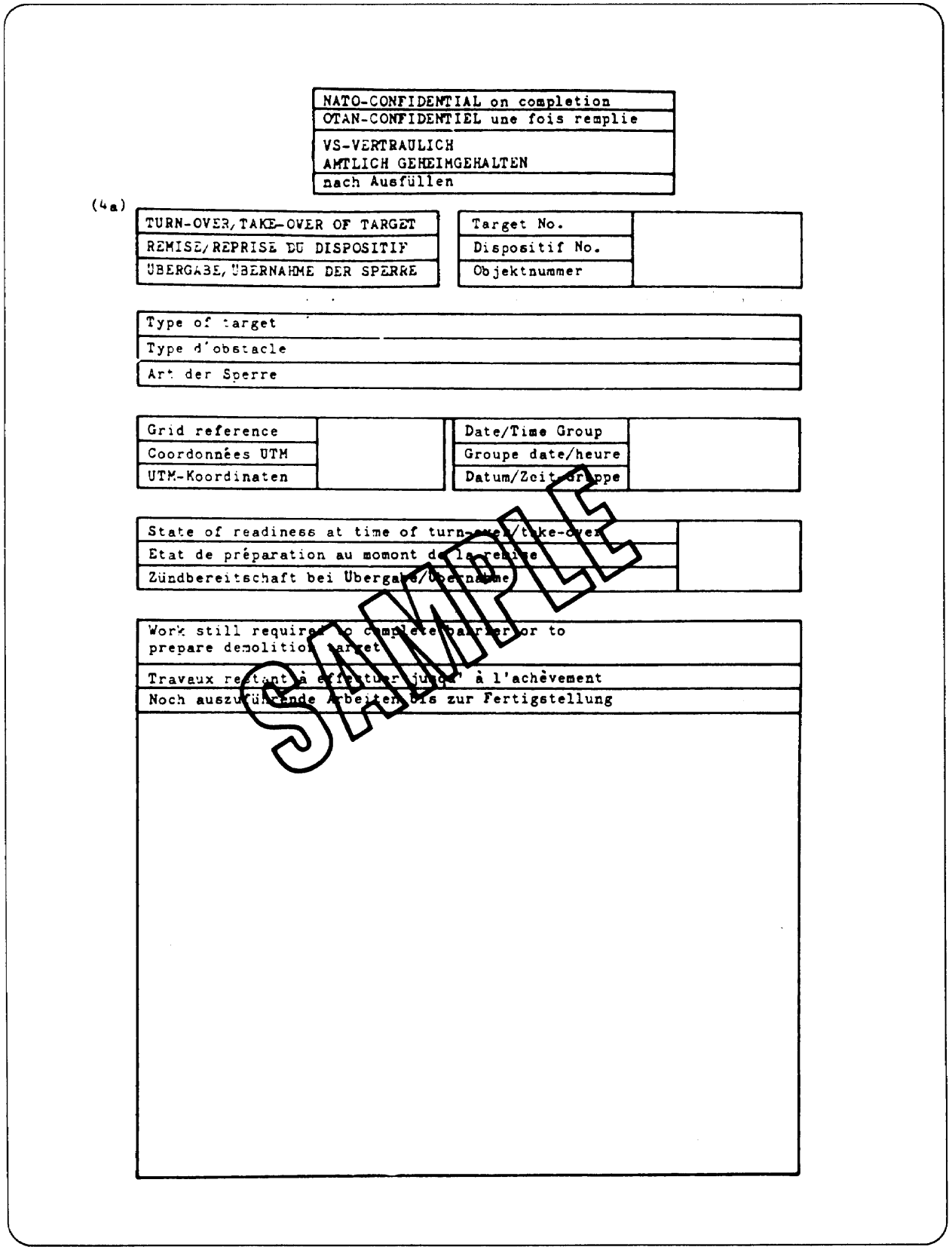


Figure F-1. Sample target folder (continued)

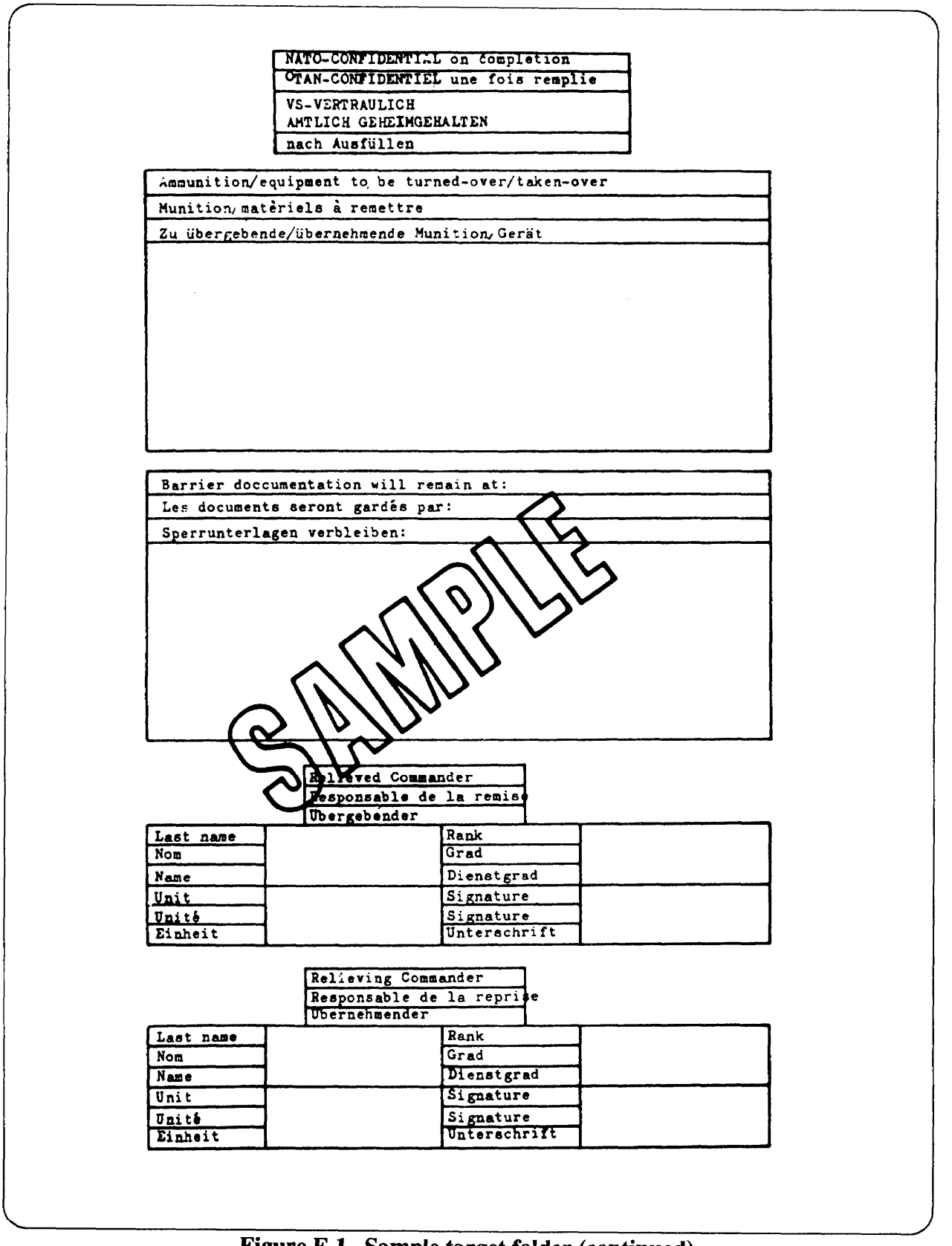


Figure F-1. Sample target folder (continued)

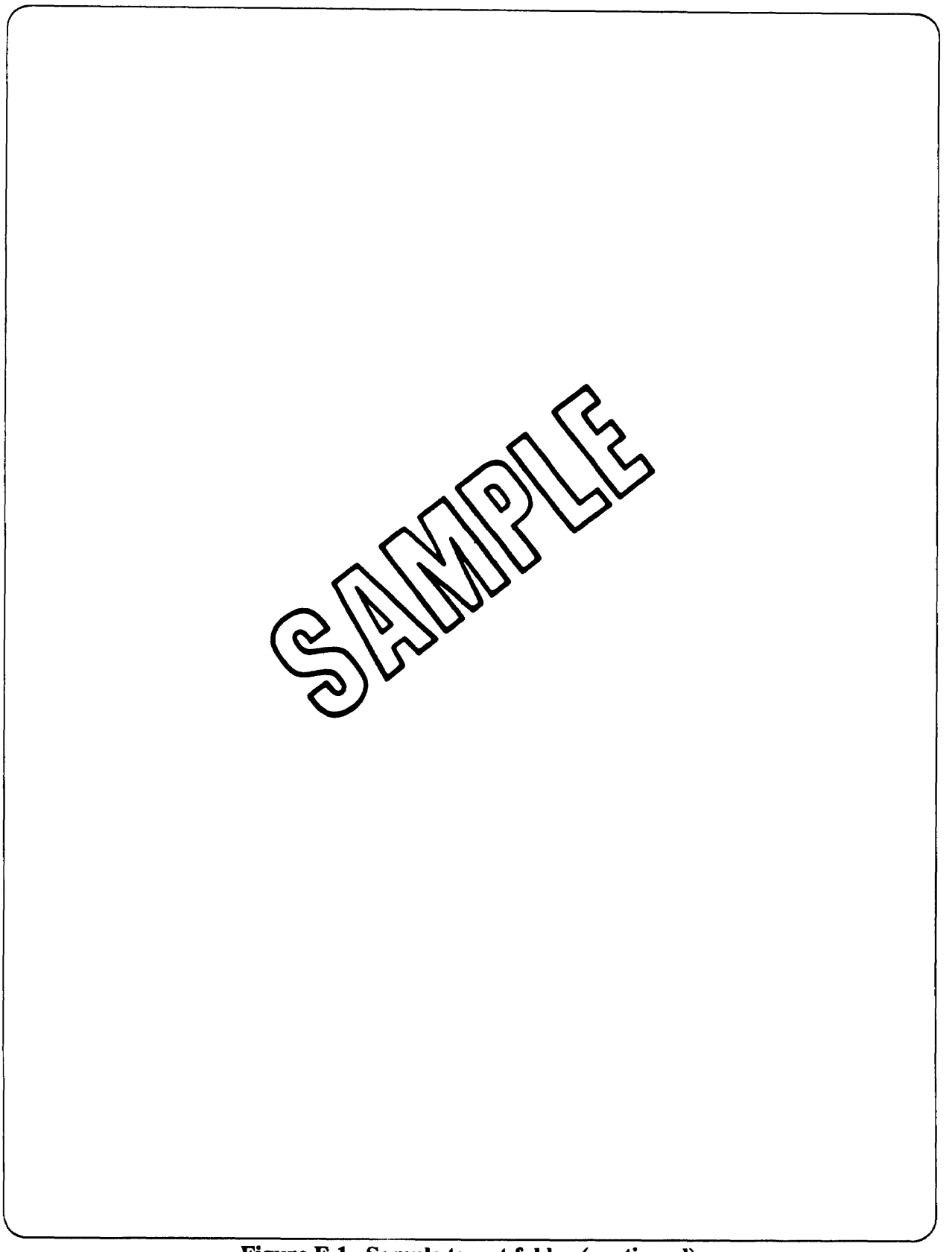


Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

(5) DEMOLITION REPORT	COMPTE RENDU DE DESTRUCTION	MELDUNG ÜBER DURCHGEFÜHRTE SPRENGUNG	
a. TARGET NO.	DISPOSITIV NO.	Objekt Nr	
b. MAP REFERENCE	COORDONNÉES	KOORDINATEN	
c. Demolition was fired at	La mise de feu a été faite à	Die Sprengung erfolgte	
Date-Time	Date-heure	Datum Zeit	
.....	.....	.....	
d. Extent of damage (1) In case of a bridge	Résultats obtenus (1) Cas d'un pont	Umfang der Zerstörungen (1) im Falle einer Brücke	
Width of gap ..... meters	Largeur de la brèche ..... mètres	Weite der Unterbrechung ..... m	
NO. of spans down	No. de travées détruites	Anzahl der herabgefallenen Strecken	
(2) In a road or runway size, depth and location of craters:	(2) Sur une route ou piste: Dimensions, profondeur et emplacement des entonnoirs:	(2) Auf einer Straße oder Rollbahn: Größe, Tiefe und Lage von Trichtern	
(3) Mines laid, type and number	(3) Mines posées, type et nombre	(3) Anzahl und Art verlegter Minen	
(4) Any other details	(4) Autres renseignements	(4) Sonstige Anmerkungen	

SAMPLE

Figure F-1. Sample target folder (continued)

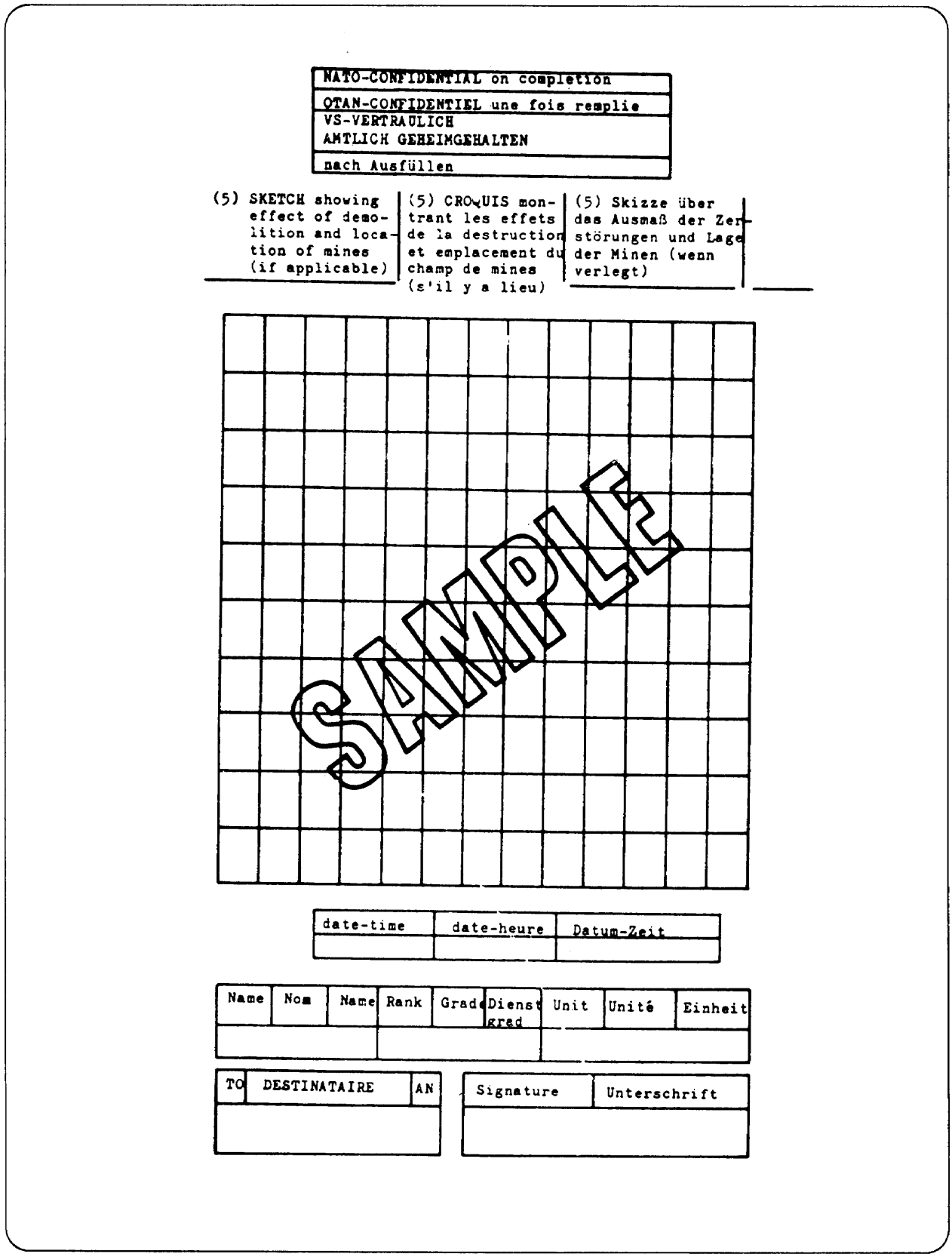


Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH
AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

TABLE OF CONTENTS

	Target Identification	Front Cover
(1)	Photograph of Target	Page 2
(1a)	Map of Target, Prestock Point and Route between	Page 3
(1b)	Map of Target, Large Scale	Page 5
(2)	Prestock Point, Transport required Route, Travel Distance, Explosives, required, Data	Page 6
(2a)	Map of Prestock Point, Large Scale	Page 7
(2b)	Sketch, Layout Plan of Prestock Point	Page 8
(2c)	Ammunition Storage Facility (Authorisation, Keys, Opening instructions	Page 9
(2d)	Explosives Stores, Mines required	Page 12
(3)	Demolition Order, Minefield record	Page 16
(3a)	Special Technical instructions	Page 17
(3b)	Sketch of Target	Page 19
(3c)	Sketch of Charges	Page 21
(3d)	Sketch of Ignition System	Page 23
(3e)	Minefield	Page 24
(4)	Hand-over/Take-over	Page 25
(5)	Demolition Report	Page 29
(6)	Official Signature	Page 32

INHALTSVERZEICHNIS

	Identifizierung des Sperrobjekts	Vordere Umschlagseite
(1)	Fotografie des Sperrobjekts	Seite 2
(1a)	Karte des Objekts, des Munitionslagerplatzes und des Marschweges zwischen beiden	Seite 3
(1b)	Karte des Objekts in großem Maßstab	Seite 5
(2)	Munitions-Lagerplatz erforderlicher Transportraum, Marschweg, Entfernung, erforderliche Sprengmittel	Seite 6
(2a)	Karte des Munitions-Lagerplatzes in großem Maßstab	Seite 7
(2b)	Lageskizze des Munition -Lagerplatzes	Seite 8
(2c)	Munitionslagerhaus(Öffnungsanweisung, Berechtigungsnachweis, Schlüssel)	Seite 9
(2d)	Erforderliche Sprengmittel, Gerät und Minen	Seite 12
(3)	Sprengbefehl/Minensperrnachweis	Seite 16
(3a)	Technische Einzelanweisungen	Seite 17

TABLE DE MATRES

	Identification du dispositif	Recto de la 1ère page
(1)	Photographie de l'ouvrage	Page 2
(1a)	Carte montrant l'emplacement du dispositif et du centre de rattachement (préstockage) ainsi que le chemin entre les deux	Page 3
(1b)	Plan du dispositif à grande échelle	Page 5
(2)	Centre de rattachement (préstockage), véhicules nécessaires, itinéraire, distance, explosifs nécessaires, données	Page 6
(2a)	Plan du centre de rattachement (préstockage) à grande échelle	Page 7
(2b)	Croquis - plan du centre de rattachement (préstockage)	Page 8
(2c)	Dépôt de munitions (permis, directives d'ouverture, clés)	Page 9
(2d)	Explosifs, matériels mines nécessaires	Page 12
(3)	Ordre de mise de feu et/ou feuille de renseignements	Page 16
(3a)	Consignes techniques particulières	Page 17
(3b)	Croquis de l'ouvrage	Page 19
(3c)	Croquis de chargement	Page 21
(3d)	Schéma de la mise en feu	Page 23
(3e)	Champs de mines de harcèlement	Page 24
(4)	Procédé de remise	Page 25
(5)	Compte-rendu de destruction	Page 29
(6)	Signature pour manoliation	Page 32

(3b)	Trennschnittskizze	Seite 19
(3c)	Ladungsskizze	Seite 21
(3d)	Zündleitungsskizze	Seite 23
(3e)	Stürminensperre	Seite 24
(4)	Übergabe/Übernahmeverhandlungen	Seite 25
(5)	Meldung über durchgeführte Sprengung	Seite 29
(6)	Unterschrift	

SAMPLE

Figure F-1. Sample target folder (continued)

NATO-CONFIDENTIAL on completion
OTAN-CONFIDENTIEL une fois remplie
VS-VERTRAULICH AMTLICH GEHEIMGEHALTEN
nach Ausfüllen

Notes:

1. Pages 3; 7-12; 14 can be detached from the target folder and handed to the soldier detailed to pick up the barrier material.
2. The commander of the closing/executing unit will use pages 29/30 to report the results to his immediate superior.

Remarques:

1. Les pages 3; 7-12;14 peuvent être retirées du carnet de dispositif de destruction preparée et remises au responsable de l'enlévement des explosifs.
2. Le chef du détachement de protection/de mise à feu emploiera les pages 29/30 pour faire rapport à son chef immédiat.

Anmerkungen:

1. Die Seiten 3; 7-12;14 können dem Sperrheft entnommen und dem Soldaten übergeben werden, der die Sperrmittel abholt.
2. Das Ergebnis ist vom Führer der schließenden/auslösenden Einheit/Teileinheit mit Seite 29/30 an den unmittelbaren Vorgesetzten zu melden.

TARGET folder completed by | CARNET d'ALERT établi par | Sperrheft aufgestellt durch:

Name	Nom	Name	Rank	Grade	Dienstgrad	Designation	Fonction	Dienststellung
Brazeal, Gregory			SFC				Plt Ldr 657th Engr Bn.	

Signature	Unterschrift	Date	Datum
Gregory Brazeal		20 March 92	

Name	Nom	Name	Rank	Grade	Dienstgrad	Designation	Fonction	Dienststellung
Brown, David			CPT				Plt Ldr, 657th Engr Bn	

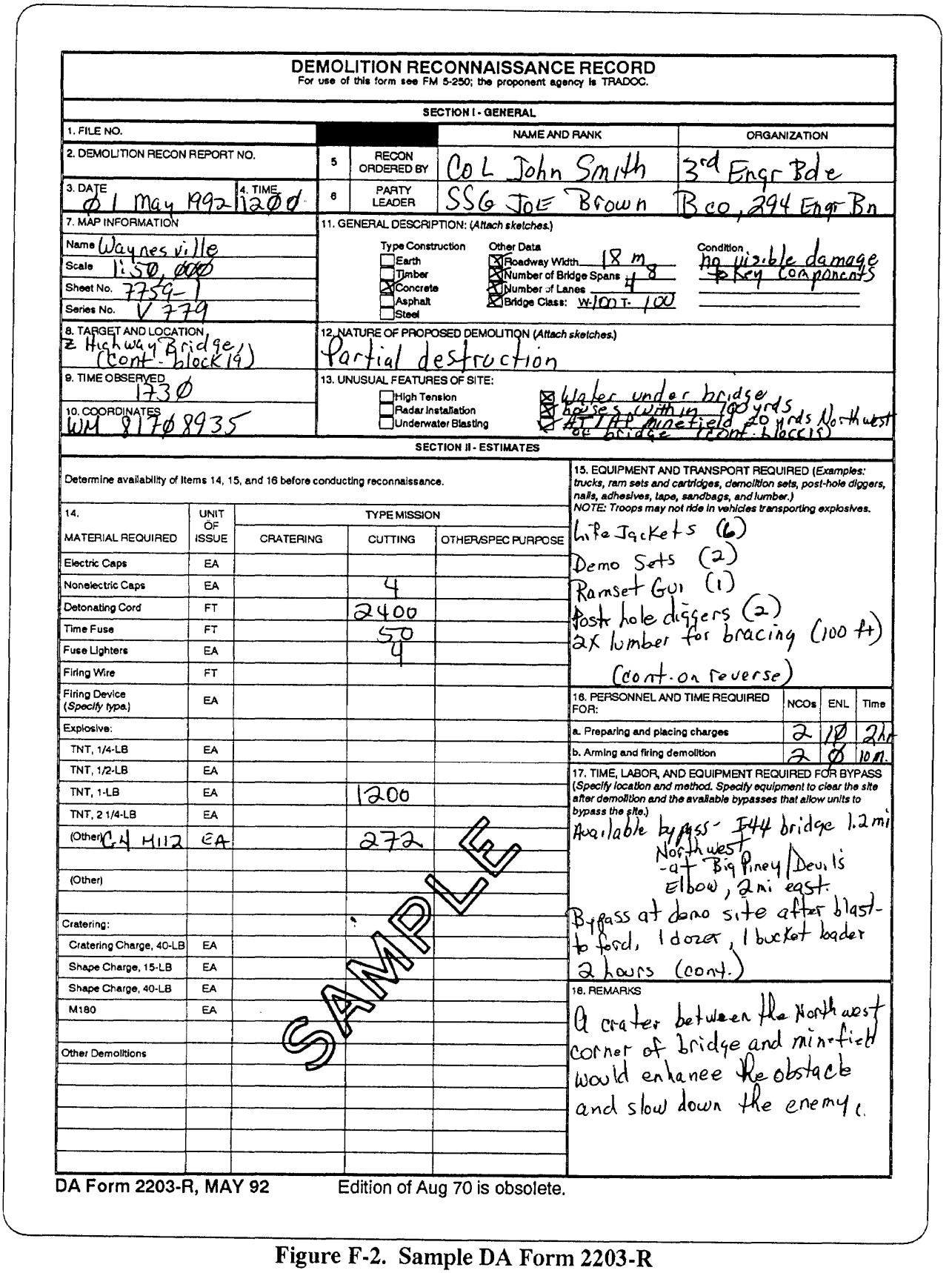
Signature	Unterschrift	Date	Datum
David Brown		20 March 92	

Folder reviewed by | Carnet controlé par | Sperrheft geprüft

Name	Rank	Designation	Date	Signature

SAMPLE

Figure F-1. Sample target folder (continued)



DEMOLITION RECONNAISSANCE RECORD
For use of this form see FM 5-250; the proponent agency is TRADOC.

SECTION I - GENERAL

1. FILE NO.		NAME AND RANK	ORGANIZATION
2. DEMOLITION RECON REPORT NO.	5 RECON ORDERED BY	COL John Smith	3rd Engr Bde
3. DATE 01 May 1992 4. TIME 1200	6 PARTY LEADER	SSG Joe Brown	B co, 294 Engr Bn

7. MAP INFORMATION
Name: Waynesville
Scale: 1:50,000
Sheet No.: 7754-I
Series No.: V 778

11. GENERAL DESCRIPTION: (Attach sketches.)
Type Construction: [ ] Earth [ ] Timber [X] Concrete [ ] Asphalt [ ] Steel
Other Data: [X] Roadway Width 18 m; [X] Number of Bridge Spans 4; [X] Number of Lanes 4; [X] Bridge Class: W-100 T-100
Condition: No visible damage to key components

8. TARGET AND LOCATION
2 Highway Bridge (cont. block 19)

12. NATURE OF PROPOSED DEMOLITION (Attach sketches.)
Partial destruction

9. TIME OBSERVED 1730

13. UNUSUAL FEATURES OF SITE:
[ ] High Tension [ ] Radar Installation [ ] Underwater Blasting
[X] Water under bridge
[X] houses within 100 yards
[X] AT/AP minefield 20 yards Northwest of bridge (cont. block 15)

10. COORDINATES WM 8170 8935

SECTION II - ESTIMATES

Determine availability of Items 14, 15, and 16 before conducting reconnaissance.

14. MATERIAL REQUIRED	UNIT OF ISSUE	TYPE MISSION: CRATERING	CUTTING	OTHER/SPEC PURPOSE
Electric Caps	EA			
Nonelectric Caps	EA		4	
Detonating Cord	FT		2400	
Time Fuse	FT		50	
Fuse Lighters	EA		4	
Firing Wire	FT			
Firing Device (Specify type.)	EA			
Explosive:				
TNT, 1/4-LB	EA			
TNT, 1/2-LB	EA			
TNT, 1-LB	EA		1200	
TNT, 2 1/4-LB	EA			
(Other) C4 M112	EA		272	
(Other)				
Cratering:				
Cratering Charge, 40-LB	EA			
Shape Charge, 15-LB	EA			
Shape Charge, 40-LB	EA			
M180	EA			
Other Demolitions				

15. EQUIPMENT AND TRANSPORT REQUIRED (Examples: trucks, ram sets and cartridges, demolition sets, post-hole diggers, nails, adhesives, tape, sandbags, and lumber.)
NOTE: Troops may not ride in vehicles transporting explosives.
Life Jackets (6)
Demo Sets (2)
Ramset Gun (1)
Post hole diggers (2)
2X lumber for bracing (100 ft)
(cont. on reverse)

16. PERSONNEL AND TIME REQUIRED FOR:	NCOs	ENL	Time
a. Preparing and placing charges	2	10	2hr
b. Arming and firing demolition	2	0	10 m.

17. TIME, LABOR, AND EQUIPMENT REQUIRED FOR BYPASS (Specify location and method. Specify equipment to clear the site after demolition and the available bypasses that allow units to bypass the site.)
Available bypass - F44 bridge 1.2 mi Northwest -at Big Piney/Devils Elbow, 2 mi east.
Bypass at demo site after blast- to ford, 1 dozer, 1 bucket loader 2 hours (cont.)

18. REMARKS
A crater between the Northwest corner of bridge and minefield would enhance the obstacle and slow down the enemy.

SAMPLE

DA Form 2203-R, MAY 92 Edition of Aug 70 is obsolete.

Figure F-2. Sample DA Form 2203-R

DEMOLITION RECONNAISSANCE RECORD

Place additional comments in the appropriate blocks.

15. EQUIPMENT AND TRANSPORT REQUIRED (*Continued*)

Rope 3/4" (200')
Hummv (1-for transport of caps)
2½-T Cargo (1-for transport of demo)
Squad vehicle (1-for transport of troops).

17. TIME, LABOR, AND EQUIPMENT REQUIRED FOR BYPASS (*Continued*)

To bridge at site 1 dozer, 1 bucket loader 3.5 hours to clear and improve approach. Ribbon Bridge Assembly - 10 interior bay, 2 end bays. 30 minutes M4T6 - 1 company, 3 hours

18. REMARKS (*Continued*)

SAMPLE

19. ADDITIONAL COMMENTS (*Specify block.*)

Block 8 cont. Bridge is over Big Piney River, near town of Devil's Elbow

Block 13 cont. Anti vehicle ditch (wheel only) on Southeast side of bridge.

PAGE 2, DA FORM 2203-R, MAY 92

Figure F-2. Sample DA Form 2203-R (continued)

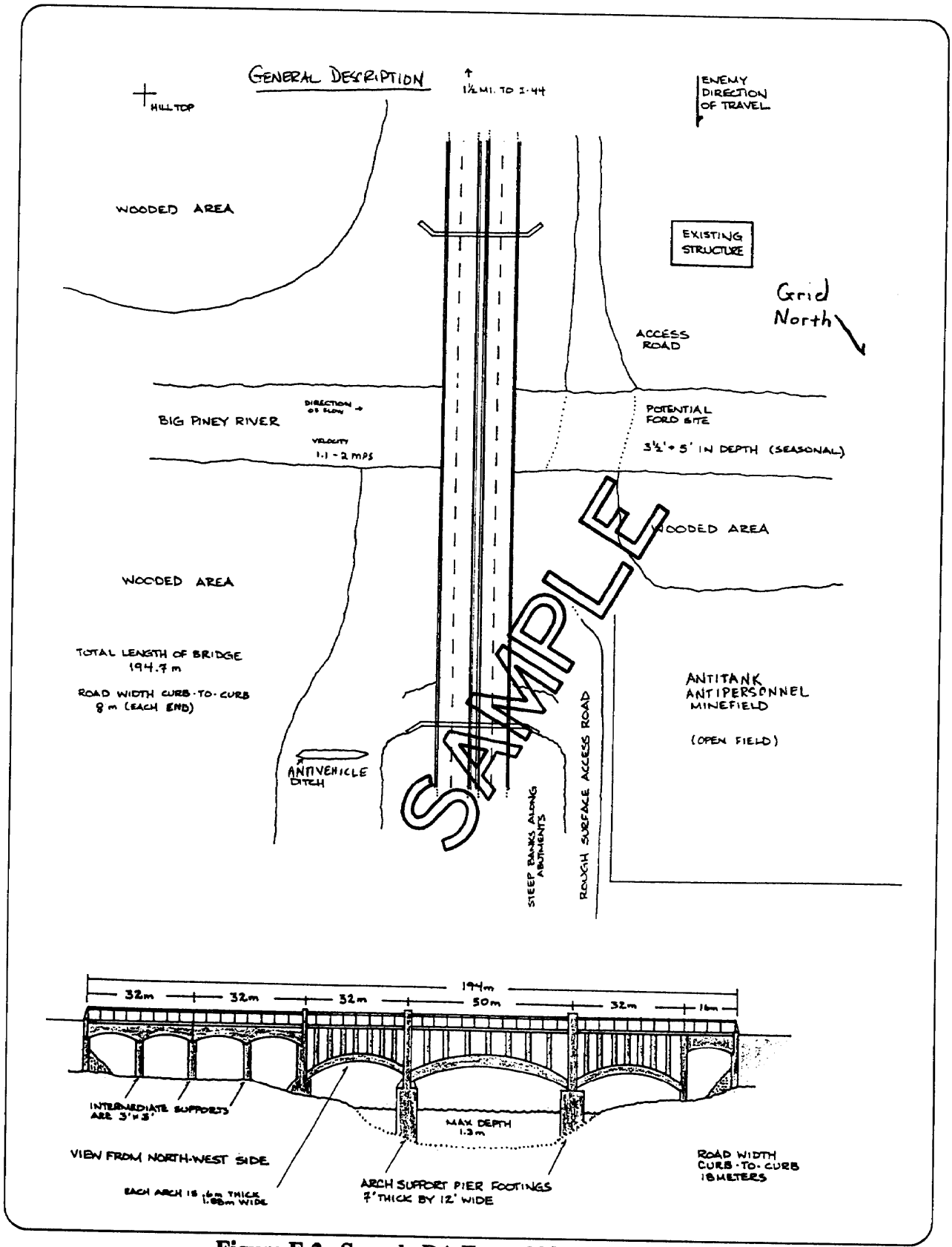


Figure F-2. Sample DA Form 2203-R (continued)

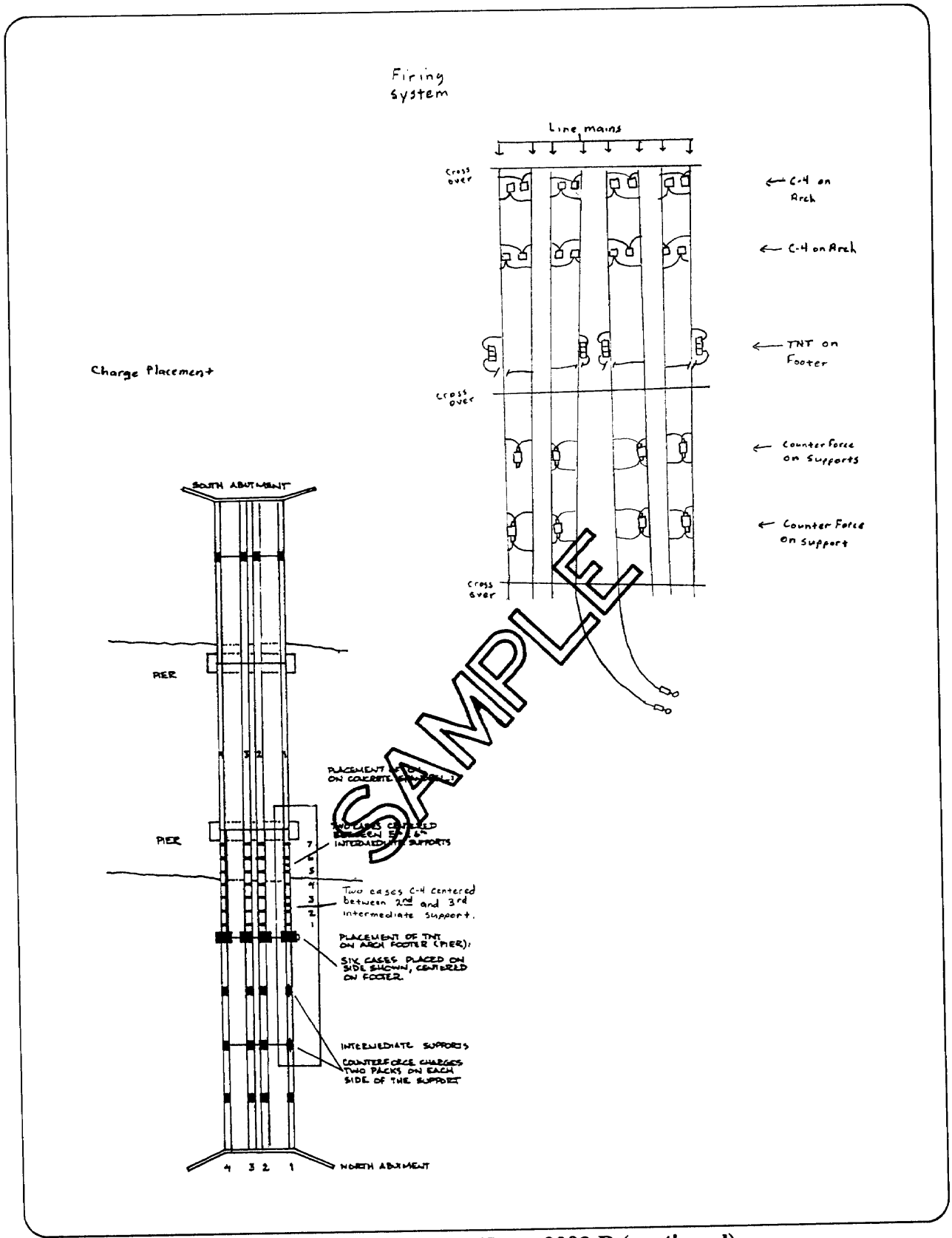
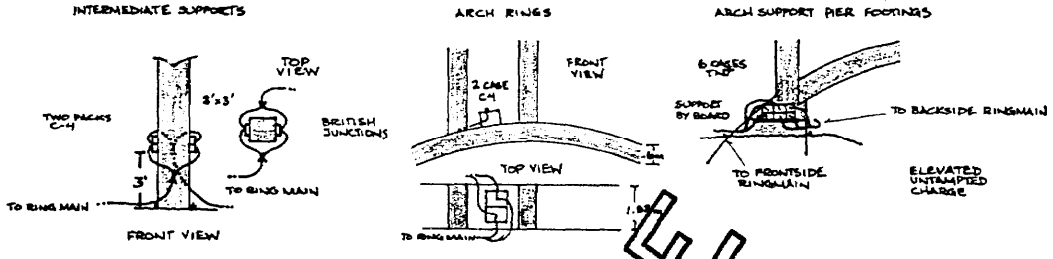


Figure F-2. Sample DA Form 2203-R (continued)

METHOD OF PRIMING
and
Charge Calculations



INTERMEDIATE SUPPORT
(USE COUNTERFORCE CHARGE)

1. CRITICAL DIMENSIONS : SUPPORT IS 3'x3'
2. SOLVE FOR TNT = (1½ LBS PER FOOT)
   1½ x 3 = 4.5 LBS OF C4 (C4 REQUIRED)
3. DIVIDE BY RE : (USING C4, RE = 1.34)
   NO CONVERSION REQUIRED. COUNTERFORCE IS CALCULATED IN C-4
4. SOLVE FOR SINGLE CHARGE PACKAGE:
   4.5 ÷ 1.25 (PKG. WT C4) = 3.6 Ø 4 PACKAGES
5. NUMBER OF CHARGES: 8 SUPPORTS
6. TOTAL REQUIRED : (STEP 4 x STEP 5)
   4 PACKAGES x 8 SUPPORTS = 32 PACKAGES

ARCH RINGS
(USE CONCRETE STRIPPING CHARGE)

1. CRITICAL DIMENSIONS
   1.88m WIDE BY .6[illegible]
2. SOLVE FOR TNT
   1.5(3.3x.6+.5)
   1.5 (2.48)
   1.5 (1.49)
   22.875 x 1.88 =
   43.005 ÷ .45 =
3. DIVIDE BY RE. (RE. FOR C4 = 1.34)
   95.67 ÷ 1.34 = 71.4[illegible] LBS C4
4. SOLVE FOR SINGLE CHARGE PKG:
   [illegible] PER ARCH CUT
5. NUMBER OF CUTS: 8
6. TOTAL REQUIRED: (STEP 4 x STEP 5)
   57 x 8 = [illegible] PACKAGES
   [illegible] PER BOX = 15.2 CASES
   [illegible] 16 cases

ARCH FOOTING
(USE BREACHING FORMULA) P = R³KC

1. CRITICAL DIMENSIONS : PIER IS 2½'x7'x9'
2. SOLVE FOR TNT: R = 7' T³ = 343
   K FOR REINFORCED CONCRETE 7'OR 7 = .54
   C FOR ELEVATED UNTAMPED = 1.8
   343 x .54 x 1.8 = 333.39
3. DIVIDE BY R.E. : (R.E. FOR TNT = 1)
   333.39 ÷ 1 = 333.39
4. SOLVE FOR SINGLE CHARGE PACKAGE:
   333.39 ÷ 1 (1 LB PKG OF TNT) = 333.39
   333.39 Ø = 334 PACKAGES
5. NUMBER OF CHARGES = 4 PIER
6. TOTAL REQUIRED: (STEP 4 x STEP 5)
   334 x = 1336 PACKAGES
   (56 PKG PER BOX = 23.8 CASES)
   23.8 Ø = 24 cases

SAMPLE

Figure F-2. Sample DA Form 2203-R (continued)

Appendix G
Explosives Identification

G-1. Purpose. The purpose of this appendix is to provide a quick reference for demolition materials common to combat engineering. The following is not a comprehensive list and is subject to change.

G-2. Demolition Materials (By Item). Table G-1 lists materials by type, item, status, national stock number (NSN), and Department of Defense identification code (DODIC). To avoid problems when requesting materials, use current supply publications.

Table G-1. Demolition materials

Type	Item	Status	NSN	DODIC
Initiating and Priming Devices				
Electric Blasting Caps	M6, Special	Live	1375-00-028-5224	M130
	Electric Cap	Inert	1375-00-621-8370	M098
Nonelectric Blasting Caps	JI	Live	1375-00-028-5226	M131
	M7	Live	1375-01-057-6439	M131
	Nonelectric Cap	Inert	1375-00-621-8362	M097
Electric Squibs	M1, Flash-Vented	Live	1377-00-219-8567	M842
	M1A1, Flash-Vented	Live	1377-00-691-1075	M851
	M1, Commercial	Live	1377-00-028-5205	M851
	Squib, Closed-End	Live	1377-00-837-3337	M900
Detonator	M1, Concussion	Live	1375-00-028-5173	M540
Firing Devices and Coupling Bases and Bodies	M1, Pull	Live	Replaced by M142	ML03
	M1A1, Pressure	Live	Replaced by M142	ML03
	M3, Tension	Live	Replaced by M142	ML03
	M5, Pressure-Release	Live	1375-00-028-5190	M627
	M142, Multipurpose	Live	1375-01-040-1526	ML03
	M122, Device	Live	1375-01-021-0606	ML02
	M1, Delay	Live	1375-00-028-5175	M616
	Coupling Base	Live	1375-00-699-5236	M327
Destructor	M10, Universal	Live	1375-00-028-5171	M241

Table G-1. Demolition Materials (continued)

Type	Item	Status	NSN	DODIC
Military Explosives				
TNT	1/4-Pound	Live	1375-00-926-9394	M030
	1/2-Pound	Live	1375-00-028-5140	M031
	1-Pound	Live	1375-00-028-5142	M032
Composition C4	M5A1	Live	1375-00-028-5148	M038
	M112	Live	1375-00-724-7040	M023
Sheet Explosives	M118	Live	1375-00-728-5941	M024
	M186	Live	1375-00-728-4108	M060
Dynamite	M1	Live	1375-00-724-9613	M591
Special-Purpose Charges				
Cratering Charge	40-Pound	Live	1375-00-028-5145	M039
Shaped Charges	M2A4, 15-Pound	Live	1375-00-028-5237	M420
	M3, 40-Pound	Live	1375-00-088-6691	M421
	40-Pound	Live	1375-00-630-3074	M992
Demolition Assemblies	M183	Live	1375-00-926-3985	M757
	M37	Live	1375-00-028-5245	M756
Bangalore Torpedos	M1A1	Live	1375-00-028-5247	M026
	M1A2	Live	1375-00-926-1948	M028
Projected Charges (Demolition Kits)	M157	Live	1375-00-729-4632	M444
	M173	Live	1375-00-812-3972	M443
	M58A2/4/5	Live	1375-01-133-4189	M913
	M68A2	Inert	1375-01-125-6521	M914
	MICLIC, Rocket	Live	1340-01-118-2838	J143
	M180	Live	1375-00-148-7159	M965
	M270	Inert	6920-01-087-0038	—
Boobytrap Simulators	M117, Flash	Live	1370-00-028-5256	L598
	M118, Illuminating	Live	1370-00-028-5257	L599
	M119, Whistling	Live	1370-00-028-5255	L600
	Hand Grenade	Live	1370-00-752-8124	L601
Smoke Grenades	M18, Green	Live	1330-00-289-6851	G940
	M18, Yellow	Live	1370-00-289-6854	G945
	M18, Red	Live	1330-00-289-6852	G950
	M18, Violet	Live	1330-00-289-6853	G955

Table G-1. Demolition Materials (continued)

Type	Item	Status	NSN	DODIC
Demolition Accessories	M4, Fuel Thickener	Live	1365-00-926-4076	K917
	M700, Time Fuse	Live	1375-00-028-5149	M670
	Time Fuse	Inert	1375-00-628-9033	M671
	M60, Fuze Igniter	Live	1375-00-691-1671	M766
	Detonating Cord	Live	1375-00-965-0800	M456
	Detonating Cord	Inert	1375-00-621-8373	M458
	Priming Adapter	—	1375-00-565-4141	M002
	M8, Cap Holder	—	1375-00-926-4105	M166
	M2, Crimpers	—	5120-00-029-0683	—
	Galvanometer	—	6625-00-539-8444	—
	BA245/U Battery	Live	6135-00-128-1632	—
	BA2245/U Battery	Live	6135-00-833-9909	—
	M51, Test Set	—	6625-00-999-3454	—
	Blasting Machine, 10-Cap	Live	1375-00-782-5541	—
	Blasting Machine, 10-Cap	Live	1375-00-935-9173	—
	Blasting Machine, M32	Live	1375-00-212-4614	—
	Blasting Machine, M34	Live	1375-00-567-0223	—
	DR8, Reel	—	8130-00-407-7859	—
	RL39A, Reel Cable	—	3895-00-498-8343	—
	18AWG, Firing Wire	—	6145-00-299-6172	—
	Electric Wire	—	6145-00-542-3968	—
	Electric Wire	—	6145-00-284-0394	—
	Detonating-Cord Clip	—	1375-00-212-4602	—
US Mines				
Antipersonnel	M14	Live	1345-00-028-5108	K121
	M17T34, Practice	Live	1345-00-348-2576	K122
	M16	Live	1345-00-173-2714	K092
	M16A1	Live	1345-00-529-7303	K092
	M16A2	Live	1345-00-965-0742	K092
	M16	Inert	1345-00-799-7391	K150
	M26	Live	1345-00-678-9822	K146
	M18A1	Live	1345-00-710-6946	K143
	M1, Chemical	Live	1345-00-289-6938	K260

Table G-1. Demolition Materials (continued)

Type	Item	Status	NSN	DODIC
Antitank	M15	Live	1345-00-028-5118	K180
	M12	Practice	1345-00-028-5117	K230
	M20	Practice	1345-00-344-2368	K231
	M21	Live	1345-00-729-4263	K181
	M69	Practice	1345-00-182-3148	K233
	M23, Chemical	Live	1345-00-542-1580	K257
GEMSS	M128, Dispenser	—	1095-00-397-3456	—
	M75, AT Mine	Live	1345-01-078-4104	K184
	M74, AP Mine	Live	1345-01-076-3497	K151
	M79	Practice	1345-01-074-9370	K234

G-3. Demolition Materials (By DODIC). Use Table G-2 to cross reference demolition materials by DODIC. Materials are listed by DODIC in ascending order and by nomenclature:

Table G-2. DODIC index for demolition materials

DODIC	Nomenclature	DODIC	Nomenclature
K001	Activator, AT Mine, M1	K065	Fuze, AT Mine, M606
K002	Activator, AT Mine, Practice, M1	K066	Fuze, AT Mine, Disp, M56
K003	Activator, AT Mine, M2	K067	Fuze, F/M21
K004	Trip Wire Assembly, F/M16A2	K090	Mine, AP, M2
K005	Intervalometer, SUU, 38/A	K091	Mine, AP, Inert, M2
K008	Firing Device, AP Mine, M57	K092	Mine, AP, M16
K009	Firing Device, AP Mine, XM123	K105	Mine, AP, Practice, M8
K010	Burster, Incendiary, M4	K120	Mine, AP, M3
K013	Spool, AP Mine	K121	Mine, AP, M14
K015	Disp and Mine, Aircraft, Practice, M132	K122	Mine, AP, Practice, M17T34
K016	Disp and Mine, Aircraft, Training, M133	K139	Mine, AP, Practice, M68
K018	Can, Crew Trainer, M133	K140	Mine, AP, Empty, M3
K020	Disp and Mine, Aircraft, M56	K141	Mine, AP, M18
K021	Intervalometer, System, F/M47	K143	Mine, AP, M18
K027	Chg, Mine-Ejection	K144	Mine, AP, Inert, M18
K028	Chg, Mine-Ejection	K145	Mine, AP, M18A1
K030	Primer-Igniter, AP Mine, Fuze, M10A1	K146	Mine, AP, M26
K031	Primer-Igniter, AP Mine, Fuze, M10A2	K150	Mine, AP, Inert, M16
K040	Chg, Spotting, AP Mine, M8	K151	GEMSS, AP, M74
K041	Chg, Spotting, AP Mine, M8A1	K170	Mine, AT, M7
K050	Fuze, AT Mine, M603	K250	Mine, AT, M19
K051	Fuze, AT Mine, M604	K917	Thickener, Fuel
K054	Fuze, AP Mine, Combination, M7A1	M001	Adapter, Priming, Plastic, M1A3 (Rnd)
K055	Fuze, AP Mine, Combination, M10A1	M002	Adapter, Priming, Plastic, M1A4 (Hex)
K056	Fuze, AP Mine, Combination, M10A2	M020	Chg, Shaped, RDX, 0.062-Lb
K058	Fuze, AP Mine, Combination, M605	M022	Chg, Shaped, PETN, 827-Lb
K060	Fuze, AT Mine, M619	M023	Chg, Block, C4, 1.25-Lb
K061	Fuze, AT Mine, XM608	M024	Chg, Block, PETN or RDX, 2-Lb
K062	Fuze, Mine FMU-30/B	M025	Chg, C4, HE, M58/M58A1, 2,000-Lb
K063	Fuze, Mine, Inert, FMU-30/B	M026	Kit, Demo, Bangalore Torpedo, M1A1
K064	Fuze, AT Mine, M616		

Table G-2. DODIC Index for Demolition Materials (continued)

DODIC	Nomenclature	DODIC	Nomenclature
M027	Chg, Block, Practice, MK37-0	M091	Cap, SP Electric, 10-Sec Delay
M028	Kit, Demolition, Lin, PETN, 0.75-Lb	M092	Cap, SP Electric, 11.2-Sec Delay
M029	Chg, Flex, Lin, PETN, 0.75-Lb	M093	Cap, SP Electric, 12.5-Sec Delay
M030	Chg, Block, TNT, 0.25-Lb	M094	Cap, SP Electric, 14-Sec Delay
M031	Chg, Block, TNT, 0.5-Lb	M095	Cap, SP Electric, 15.6-Sec Delay
M032	Chg, Block, TNT, 1-Lb	M097	Cap, Nonelectric, Practice
M034	Chg, Block, TNT, 8-Lb	M098	Cap, Electric, Inert
M035	Chg, Chain, TNT, 20-Lb	M101	Cap, SP Electric, 0.8-Sec Delay
M036	Chg, Chain, TNT, 2.5-Lb	M102	Cap, SP Electric, 1.4-Sec Delay
M037	Chg, Block, C2, 2.25-Lb	M103	Cap, SP Electric, 2.2-Sec Delay
M038	Chg, Block, C4, 2.25-Lb	M104	Cap, SP Electric, 2.9-Sec Delay
M039	Chg, Block, Cratering, 40-Lb	M107	Cap, SP Electric, 3.7-Sec Delay
M040	Chg, Block, TNT, 55-Lb	M108	Cap, SP Electric, 4.5-Sec Delay
M041	Chg, Block, C2, 0.5-Lb	M109	Cap, SP Electric, Instantaneous
M043	Chg, Block, TNT, 49-Lb	M110	Cap, Electric, High-Strength
M044	Chg, Block or Shaped, HDX1, 12-Lb	M112	Cap, Elec, Nonsubmersible, Prac, M10
M046	Chg, Flex, Lin, Comp A, MK8-3, 50-Lb	M117	Cap, SP Electric, 5.3-Sec Delay
M048	Chg, Block, C2, 2.5-Lb	M118	Cap, SP Electric, 6.4-Sec Delay
M051	Chg, Lin, Prac, M68/M68A1, 2,000-Lb	M120	Cap, Electric, No. 8
M065	Chg, Block, H6, 4-Lb	M125	Cap, Electric, No. 8, 2nd Delay
M060	Chg, Roll, PETN, M186, 25-Lb	M126	Cap, Electric, No. 8, 3rd Delay
M078	Cap, Electric, Nonsubmersible, M4	M127	Cap, Electric, No. 8, 4th Delay
M080	Chg, Flex, Lin, Prac, PETN, 0.007-Lb	M128	Cap, SP Electric, 7.6-Sec Delay
M081	Chg, Flex, Lin, PETN, 14-Oz	M129	Cap, Electric, SP-Strength
M082	Chg, Flex, Lin, PETN, 22-Oz	M130	Cap, SP Electric, Submersible, J2/M6
M083	Chg, Flex, Lin, PETN, 28-Oz	M131	Cap, Nonelectric, Nonsubmersible, M7
M084	Chg, Flex, Lin, PETN, 36-Oz	M138	Cap, Electric, Nonsubmersible
M085	Chg, Flex, Lin, PETN, 43-Oz	M153	Cap, Electric, Nonsubmersible
M086	Chg, Flex, Lin, PETN, 50-Oz	M236	Destructor, Explosive, PETN
M087	Chg, Flex, Lin, PETN, 57-Oz	M240	Destructor, Explosive, PETN

Table G-2. DODIC Index for Demolition Materials (continued)

DODIC	Nomenclature	DODIC	Nomenclature
M241	Destructor, Explosive, Universal, M10	M605	Destroyer, Document, Emergency, Incindiary, M1A2, TH4
M327	Base, Coupling, with Primer	M606	Destroyer, Crypto Equip, M1A2, TH4
M328	Base, Coupling, without Primer	M607	Destroyer, Crypto Equip, M2A1
M405	Chg, Propelling, Earth Rod, M112	M608	Destroyer, Crypto Equip, TH4
M418	Chg, Shaped, RDX, MK47-0, 1.5-Lb	M609	Destroyer, Crypto Equip, M2A1, TH4
M420	Chg, Shaped, Comp B, M2A4/M2A3E1, 15-Lb	M610	Destroyer, File, Incindiary, ABC-M4
M421	Chg, Shaped, Comp B, M3A2, 40-Lb	M611	Destroyer, File, Incindiary, ABC-M4
M431	Chg, Rigid, Lin, Amatol, 35-Lb	M612	Destroyer, Incindiary, TH3
M442	Kit, Demolition, Practice, M174	M615	Igniter, Document Destroyer, M25
M443	Kit, Demolition, Projected-Chg, M173	M616	Device, Firing, M1, 6- to 14-Min Delay
M444	Kit, Demolition, Projected-Chg, M157	M617	Set, Device, Firing, M1
M446	Kit, Demolition, Projected-Chg, M1	M619	Device, Firing, M1, 12- to 32-Min Delay
M455	Cord, Detonating, Primacord, PETN	M620	Device, Firing, M1, 45- to 115-Min Delay
M456	Cord, Detonating, Reinforced, Waterproof	M622	Device, Firing, M1, 210- to 570-Min Delay
M457	Cord, Detonating, PETN	M623	Device, Firing, M1, 610- to 1,130-Min Delay
M458	Cord, Detonating, Inert	M624	Device, Firing, Brass
M466	Detonator, Percussion, MK2	M625	Device, Firing, Zinc
M482	Chg, Steel	M626	Device, Firing, Zinc
M483	Chg, Controlled, Steel	M627	Device, Firing, Steel
M485	Cutter, HE, 1-Inch Jaw	M629	Device, Firing, M3
M486	Cutter, HE, 2-Inch Jaw	M630	Device, Firing, Pull-Type, M1
M540	Kit, Detonator, Percussion, M1	M631	Device, Firing, Pressure-Release, M1
M541	Detonator, Friction, M2, 8-Sec Delay	M632	Device, Firing, Zinc
M559	Kit, Demolition, M175	M635	Device, Firing, Pull-Type, M1
M587	Dynamite, Nitrogylcerin	M637	Device, Firing, Zinc
M591	Dynamite, Military, M1	M639	Device, Firing, Pressure-Release, M5
M598	Destroyer, Crypto Equip, M1A2	M641	Device, Firing, Tension-Release
M600	Destroyer, Crypto Equip, Incindiary, M2A1	M643	Device, Firing, Tension-Release
M601	Destroyer, Crypto Equip, Incindiary, M1A2, TH1	M644	Device, Firing, Aluminum

Table G-2. DODIC Index for Demolition Materials (continued)

DODIC	Nomenclature	DODIC	Nomenclature
M650	Device, Firing, Aluminum	M975	Fuze, Crypto Equip, M210, 0.7-Sec Delay
M670	Fuse, Timed, M700	M976	Chg, Block, Comp H6, 4-Lb
M671	Fuse, Timed, Inert	M977	Cord, Detonating, PETN
M680	Cylinder, Ignition, Flame-Thrower, M1	M980	Chg, Roll, PETN, 20-Lb
M745	Kit, Conversion, Depth-Chg	M981	Chg, Roll, PETN, 20-Lb
M756	Assembly, Chg, M37, 20-Lb	M982	Chg, Roll, PETN, 20-Lb
M757	Assembly, Chg, C4, M183	M983	Chg, Roll, PETN, 20-Lb
M767	Igniter, Fuse, Timed, Practice, XM77	M984	Chg, Roll, PETN, 20-Lb M766
M784	Chg, Shaped, Practice, Inert, MK37-1, 7-Lb	M986	Chg, Roll, PETN, 20-Lb
M790	Assembly, Comp C2 or C3, MK127-0, 20-Lb	M987	Chg, Block, C4, 2-Lb
M791	Assembly, Tetrytol, MK133-0, 20-Lb	M988	Chg, Block, C4, 0.5-Lb
M792	Assembly, Block, C4, MK138-0, 20-Lb	M989	Initiator, Explosive
M810	Primer, Percussion, Improved, No. 3	M990	Detonator, Flash
M814	Destroyer, Document, 55-Gal, M4	M992	Chg, Shaped, Practice, Inert, M3, 40-Lb
M820	Kit, Explosive, Earth Rod, No. 1	M993	Chg, Roll, PETN, 20-Lb
M821	Kit, Explosive, Foxhole-Digger	M994	Chg, Roll, PETN, 20-Lb
M832	Chg, Shaped, Comp H6, MK74-1, 1.5-Lb	M995	Chg, Lin, Comp H6, MK86-0, 0.002-Kg
M833	Chg, Shpd, Practice, Inert, MK74-0, 1.3-Lb	M996	Chg, Lin, Comp H6, MK87-0, 0.013-Kg
M836	Cap, Elec, Dry, Instantaneous	M997	Chg, Lin, Comp H6, MK88-0, 1-Kg
M855	Cap, Elec, Dry, 0.5-Sec Delay	M998	Chg, Rigid, Lin, Comp C3, MK89-0, 14-Kg
M910	Igniter, Primer and Base, XM110	ML03	Device, Firing, Plastic, M142
M913	Chg, Flex, Lin, Comp C4, M58A1, 2,000-Lb	ML04	Cutter, HE
M914	Chg, Lin, Practice, M68A1, 2,000-Lb	ML05	Cutter, HE
M916	Chg, Shpd, Practice, Inert, MK47-0, 1.5-Lb	ML07	Cap, Electric, Nonsubmersible
M936	Chg, Block, Inert, 0.25-Lb	ML08	Kit, Demolition, XM268
M957	Chg, Shaped, Comp H6, MK47-0, 1.13-Lb	ML09	Chg, Shaped, Flex, Lin, 20-Gr/Ft
M965	Kit, Cratering, M180	ML10	Chg, Shaped, Flex, Lin, 30-Gr/Ft
M974	Cap, Electric, Submersible	ML11	Chg, Shaped, Flex, Lin, 40-Gr/Ft

Table G-2. DODIC Index for Demolition Materials (continued)

DODIC	Nomenclature	DODIC	Nomenclature
ML12	Chg, Shaped, Flex, Lin, 60-Gr/Ft	MW30	Kit, Demo, Bangalore Torpedo, M1 or M1A1
ML13	Chg, Shaped, Flex, Lin, 75-Gr/Ft	MW31	Holder, Detonator, MK2-0
ML14	Chg, Shaped, Flex, Lin, 125-Gr/Ft	MW30	Kit, Demo, Bangalore Torpedo, M1 or M1A1
ML15	Chg, Shaped, Flex, Lin, 225-Gr/Ft	MW31	Holder, Detonator, MK2-0
ML16	Chg, Shaped, Flex, Lin, 300-Gr/Ft	MW37	Driver, Power-Actuated, MK22-0
ML17	Chg, Shaped, Flex, Lin, 400-Gr/Ft	MW38	Float, Rigid, Polyurethane
ML18	Chg, Shaped, Flex, Lin, 500-Gr/Ft	MW49	Connector, Detonating Cord, Plastic
ML19	Chg, Shaped, Flex, Lin, 600-Gr/Ft	MW52	Chg, Sheet, MK57-0
ML23	Cap, Bridge-Wire, X175E	MW53	Chg, Sheet, MK56-0
ML25	Chg, Flex, Lin, M59	MW56	Device, Safety and Arming, MK39-0
ML26	Chg, Lin, Practice, M69	MW84	Kit, Demo, Tubular SWS, MK75-0
ML27	Detonator, Percussion, MK53	MW85	Kit, Accessory, Demolition, MK29-0
ML32	Primer, Percussion, M27	MW86	Kit, Firing Device, MK48-0
ML36	Kit, Fuze, Inert, M1147	MW87	Kit, Firing Device, Training, MK122-0
ML37	Kit, Fuze, Live, M1133	MX14	Kit, Centering, Cavity Chg
ML78	Chg, Shaped, Practice, MK47-0	MY01	Clip, Detonating Cord, M1
ML82	Kit, Fuze, Live, M1134	SS89	Chg, Shock-Test, R/U725
MW02	Valve, Explosive, Electrically Initiated	XW60	Kit, Firing Device, MK138-0
MW26	Cell, Arming, MK1-8, 80-Min Delay	XW65	Chg, Shock-Test, R/U1260
MW27	Clip, Detonating Cord, M1	XW66	Chg, Shock-Test, R/U1259
MW28	Connector, Plastic	XW67	Chg, Shock-Test
MW29	Element, Delay, DE, MK19-0	YW05	Kit, Chg, Training, MK75-0

Appendix H
Methods of Attacking Bridges with Demolitions

The methods of attack in this appendix are for the most common types of bridges; however, they are not all inclusive. When faced with unusual construction methods or materials (for example, Hayricks which are linear-shaped charges used by host NATO countries), the responsible engineer shouId adapt one the of the recommended methods or recategorize the bridge as a miscellaneous bridge and design the demolition using the principles in Chapter 4.

Table H-1. Minimum E_R values for bottom attack (percent)

$\frac{H}{L}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
$\frac{E_R}{L}$	0.0002	0.0008	0.0020	0.0030	0.0050	0.0070	0.0100	0.0130	0.0160	0.0200
$\frac{H}{L}$	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
$\frac{E_R}{L}$	0.0240	0.0290	0.0340	0.0390	0.0440	0.0500	0.0570	0.0630	0.0700	0.0770

NOTES:

1. The values in this table are based on the following formula:

$$\frac{E_R}{L} = [4(\frac{H}{L})^2 + 1]^{1/2} - 1$$

where—

E_R = required end clearance.
L = span length.
H = beam, truss, or bow depth (including deck).

2. If the result of $\frac{H}{L}$ is not on the chart exactly as calculated, round UP to the next higher value. For example, $\frac{H}{L} = 0.076$, use the column headed 0.08. Read down that column to determine $\frac{E_R}{L}$. In this case, $\frac{E_R}{L} = 0.013$.

3. Multiply the $\frac{E_R}{L}$ value determined from the chart by L to get E_R.

Table H-2. Minimum L_C values for top attack (midspan)

$\frac{H}{L}$ \ $\frac{L_s}{L}$	Ratio of Section Removed to Span Length ($\frac{L_c}{L}$)														
	0.004	**0.006**	**0.008**	**0.010**	**0.012**	**0.014**	**0.016**	**0.018**	**0.020**	**0.030**	**0.040**	**0.050**	**0.060**	**0.080**	**0.100**
0.01	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.009	0.010	0.011	0.013	0.015
0.02	0.005	0.006	0.007	0.008	0.009	0.010	0.011	0.011	0.012	0.015	0.017	0.019	0.022	0.026	0.030
0.03	0.008	0.009	0.011	0.012	0.014	0.015	0.016	0.017	0.018	0.022	0.026	0.029	0.033	0.039	0.045
0.04	0.011	0.013	0.015	0.016	0.018	0.019	0.021	0.022	0.023	0.029	0.034	0.039	0.043	0.052	0.060
0.05	0.013	0.016	0.018	0.020	0.022	0.024	0.026	0.028	0.029	0.036	0.043	0.049	0.054	0.065	0.075
0.06	0.015	0.019	0.022	0.025	0.027	0.029	0.031	0.033	0.035	0.044	0.051	0.058	0.065	0.078	0.090
0.07	0.018	0.022	0.026	0.029	0.031	0.034	0.036	0.039	0.041	0.051	0.060	0.068	0.076	0.091	0.105
0.08	0.021	0.025	0.029	0.033	0.036	0.039	0.042	0.044	0.047	0.058	0.068	0.078	0.087	0.104	0.120
0.09	0.023	0.028	0.033	0.037	0.040	0.044	0.047	0.050	0.053	0.065	0.077	0.087	0.097	0.116	0.135
0.10	0.026	0.032	0.036	0.041	0.045	0.049	0.052	0.055	0.058	0.073	0.085	0.097	0.108	0.129	0.150
0.11	0.028	0.035	0.040	0.045	0.049	0.053	0.057	0.061	0.064	0.080	0.094	0.107	0.119	0.142	0.165
0.12	0.031	0.038	0.044	0.049	0.054	0.058	0.062	0.066	0.070	0.087	0.102	0.116	0.130	0.155	0.180
0.13	0.033	0.041	0.047	0.053	0.058	0.063	0.067	0.072	0.076	0.095	0.111	0.126	0.140	0.168	0.195
0.14	0.036	0.044	0.051	0.057	0.063	0.068	0.073	0.077	0.082	0.102	0.119	0.136	0.151	0.181	0.210
0.15	0.038	0.047	0.054	0.061	0.067	0.073	0.078	0.083	0.088	0.109	0.128	0.145	0.162	0.194	0.225
0.16	0.041	0.050	0.058	0.065	0.072	0.078	0.083	0.088	0.093	0.116	0.136	0.155	0.173	0.207	0.240
0.17	0.043	0.053	0.062	0.069	0.076	0.082	0.088	0.094	0.099	0.124	0.145	0.165	0.184	0.220	0.255
0.18	0.046	0.056	0.065	0.073	0.080	0.087	0.093	0.099	0.105	0.131	0.154	0.175	0.194	0.233	0.270
0.19	0.049	0.060	0.069	0.077	0.085	0.092	0.099	0.105	0.111	0.138	0.162	0.184	0.205	0.246	0.285
0.20	0.051	0.063	0.073	0.081	0.089	0.097	0.104	0.110	0.117	0.145	0.171	0.194	0.216	0.259	0.300

NOTES:

1. Tabulated values are for $\frac{L_c}{L}$, from which you can calculate L_c: $L_c = \frac{L_c}{L}(L)$.
2. This table is based on the formula:

$$\frac{L_c}{L} = \frac{2H[\frac{L_s}{L} - (\frac{L_s}{L})^2]^{1/2}}{L(1/2 - \frac{L_s}{L})}$$

3. If the results of $\frac{L_s}{L}$ or $\frac{H}{L}$ are not on the chart exactly as calculated, round UP to the next higher value on the chart. For example, if $\frac{H}{L} = 0.021$, use 0.03; if $\frac{L_s}{L} = 0.0142$, use 0.016. Intersect the $\frac{L_s}{L}$ and $\frac{H}{L}$ values on the chart to get the value of $\frac{L_c}{L}$. Multiply the $\frac{L_c}{L}$ value by L to get L_c.

Table H-3. Attacks on simply supported bridges

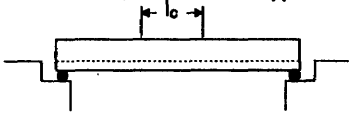
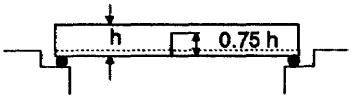
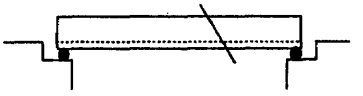
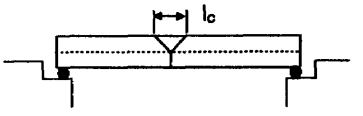
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
1	Steel Beam	Through Bridge, Method I	Top Attack: E is less than E_R  1. Cut at midspan. 2. Cut beams, including bottom flange in "V." 3. Do not consider cutting deck.	None
2		Through Bridge, Method II	Bottom Attack: E is greater than E_R  1. Cut at midspan to 0.75h, as shown. 2. Cut deck across full bridge width.	None
3		Through Bridge, Method III	Angled Attack:  1. Cut between 1/3-span and midspan. 2. Cut deck across full bridge width.	End clearance is not a consideration.
4		Through Bridge, Method IV	Bottom Attack: E is less than E_R 1. Cut at midspan to 0.75h. 2. Cut deck across full bridge width. 3. Attack one abutment or pier to create sufficient end clearance.	None
5		Through Bridge, Method V	Top Attack: E is less than E_R  1. Cut at midspan. 2. Where deck is located well above beam bottom, cut bridge as shown. 3. Do not consider cutting deck.	None

Table H-3. Attacks on simply supported bridges (continued)

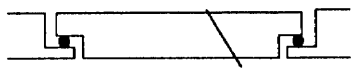
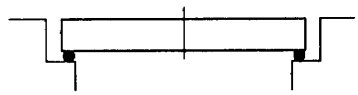
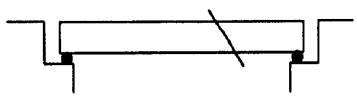
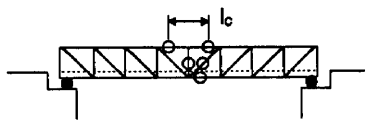
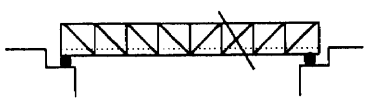
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
6	Steel Beam	Deck Bridge, Top Support	Angled Attack:  1. Cut between 1/3-span and midspan. 2. Cut deck across full bridge width.	1. Configuration found in cantilever and suspended-span bridges 2. End clearance is not a consideration.
7		Deck Bridge, Bottom Support, Method I	Bottom Attack: E is greater than E_R  1. Cut at midspan. 2. Do not consider cutting deck.	None
8		Deck Bridge, Bottom Support, Method II	Bottom Attack: E is less than E_R 1. Cut at midspan. 2. Do not consider cutting deck. 3. Attack one abutment or pier to create sufficient end clearance.	None
9		Deck Bridge, Bottom Support, Method III	Angled Attack:  1. Cut between 1/3-span and midspan. 2. Cut deck across full bridge width.	End clearance is not a consideration
10	Steel Truss	Through Bridge, Method I	Top Attack: E is less than E_R  1. Cut at midspan. 2. Cut top chord twice, vertically (if necessary), and diagonals and bottom chord. 3. Remove wind bracing over midspan. 4. Do not consider cutting deck.	None
11		Through Bridge, Method II	Angled Attack:  1. Cut between 1/3-span and midspan. 2. Cut top chord, diagonals, and bottom chord in one bay only. 3. Cut deck across full bridge width.	None

Table H-3. Attacks on simply supported bridges (continued)

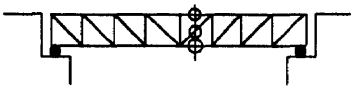
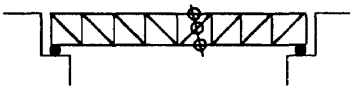
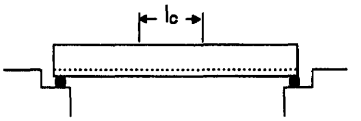
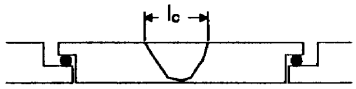
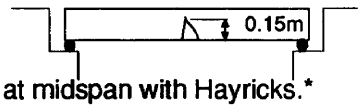
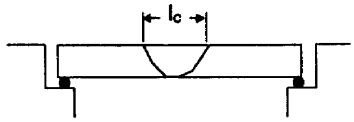
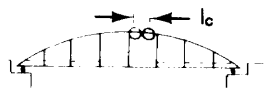
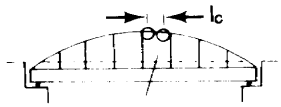
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
12	Steel Truss	Deck Bridge, Top Support	Bottom Attack: 1. Cut between 1/3-span and midspan. 2. Cut top chord, diagonals, and bottom chord in one bay only. 3. Do not consider cutting deck.	1. Configuration found in cantilever and suspended-span bridges 2. End clearance is not a consideration.
13		Deck Bridge, Bottom Support, Method I	Bottom Attack: E is greater than E_R  1. Cut at midspan. 2. Cut top chord, diagonals, and bottom chord in one bay only. 3. Do not consider cutting deck.	None
14		Deck Bridge, Bottom Support, Method II	Bottom Attack: E is less than E_R 1. Cut at midspan. 2. Cut top chord, diagonals, and bottom chord in one bay only. 3. Do not consider cutting deck. 4. Attack one abutment or pier to create sufficient end clearance.	None
15		Deck Bridge, Bottom Support, Method III	Angled Attack:  1. Cut between 1/3-span and midspan. 2. Cut deck across full bridge width.	End clearance is not a consideration
16	Concrete	Through Bridge	Bottom Attack:  1. Cut between midspan. 2. Cut deck across full bridge width.	This method applies to slab bridges only.

Table H-3. Attacks on simply supported bridges (continued)

Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
17	Concrete	Deck Bridge, Top Support	Top Attack:  Cut at midspan with a concrete-stripping charge.	1. Configuration found in cantilever and suspended-span bridges 2. Remove concrete for L_c distance to full width and depth of beams.
18		Deck Bridge, Bottom Support, Method I	Bottom Attack: E is greater than E_R  Cut at midspan with Hayricks.*	1. This method applies to slab bridges only. 2. Sufficient reinforcing bars are cut to cause bridge collapse.
19		Deck Bridge, Bottom Support, Method II	Bottom Attack: E is less than E_R 1. Cut at midspan with Hayricks.* 2. Attack one abutment or pier to create sufficient end clearance.	This method applies to slab bridges only.
20		Deck Bridge, Bottom Support, Method III	Top Attack: E is less than E_R  Cut at midspan with a concrete-stripping charge.	Remove concrete for L_c distance to full width and depth of beams.
21	Bowstring	Normal	Top Attack:  1. Cut at midspan. 2. Cut bow in two places. 3. Cut all hangers between bow cuts. 4. Do not consider cutting deck..	None
22		Reinforced Beam or Truss	Top Attack plus Girders:  1. Cut truss or beam with the appropriate method (Serials 1 through 15). 2. Cut bow in two places, including hangers.	None

Note: Hayricks are not in the US Army supply system.

Table H-4. Attacks on continuous bridges

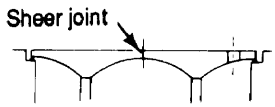
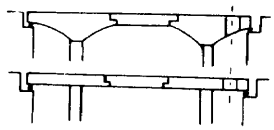
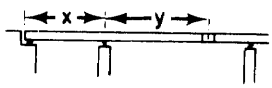
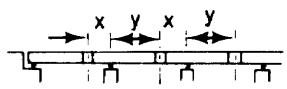
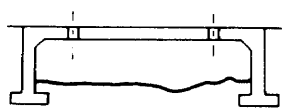
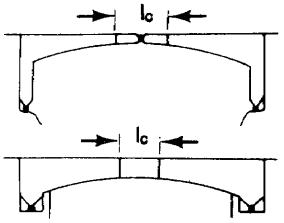
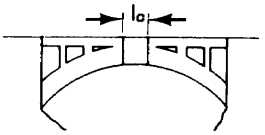
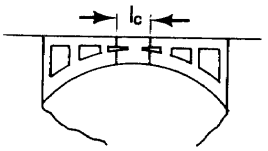
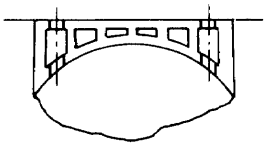
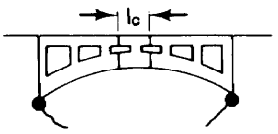
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
1	Concrete	Cantilever	Two Cuts:  1. Cut anchor span as closely to the pier as practical. 2. Cut midspan shear joint.	1. Cutting anchor span may require a two-stage attack. 2. Use a concrete-stripping charge for the first stage.
2		Cantilever and Suspended Span	One Cut:  Cut anchor as closely to the pier as practical.	1. Cutting anchor span may require a two-stage attack. 2. Use a concrete-stripping charge for the first stage. 3. If demolition of the suspended span will create the desired obstacle, regard the span as simply supported and attack accordingly.
3		Beam or Truss with Short Side Span	One Cut:  1. Cut interior span so *y* is greater than 1.25*x*. 2. If necessary, cut other interior spans as in Serial 4.	1. Cutting longer spans may require a two-stage attack. 2. Use a concrete-stripping charge for the first stage.
4		Beam or Truss without Short Span	Two or More Cuts:  Cut interior span so *y* is greater than 1.25*x*.	1. Cutting these spans may require a two-stage attack. 2. Use a concrete-stripping charge for the first stage.
5		Portal, Fixed Footing	Two Cuts:  Cut span twice, close to pier.	1. Cutting these spans may require a two-stage attack . 2. Use a concrete-stripping charge for the first stage.

Table H-4. Attacks on continuous bridges (continued)

Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
6	Concrete	Portal, Pinned Footing	Strip Concrete:  Remove concrete from midspan over length L_c with a concrete-stripping charge.	1. Remove all concrete for L_c. 2. A one-stage attack should be adequate. 3. When footing conditions are unknown, use Serial 5.
7		Arch, Open Spandrel, Fixed Footing, Method I	Strip Concrete:  Remove concrete from midspan over length L_c with a concrete-stripping charge.	1. Applies to arches greater than 35 meters 2. A one-stage attack should be adequate.
8		Arch, Open Spandrel, Fixed Footing, Method II	Strip Concrete:  1. Remove concrete from midspan over length L_c with a concrete-stripping charge. 2. Attack springing with Hayricks* at the top face of the arch ring.	1. Applies to arches greater than 35 meters 2. A one-stage attack should be adequate.
9		Arch, Open Spandrel, Fixed Footing, Method III	Four Cuts: 	1. Alternative to Method II, applies to arches greater than 35 meters 2. Two-stage attack may be required. 3. Use concrete-stripping charge for first stage.
10		Arch, Open Spandrel, Pinned Footing	Strip Concrete:  Remove concrete from midspan over length L_c with a concrete-stripping charge.	A one-stage attack should be adequate.

Note: Hayricks are not in the U.S. Army supply system.

Table H-4. Attacks on continuous bridges (continued)

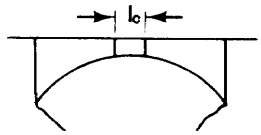
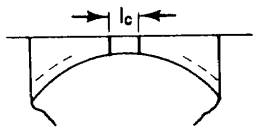
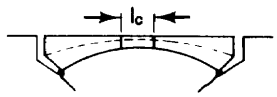
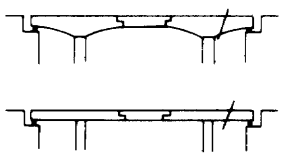
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
11	Concrete	Arch, Solid Spandrel, Fixed Footing, Method I	Strip Concrete:  Remove concrete from midspan over length L_C with a concrete-stripping charge.	A one-stage attack should be adequate.
12		Arch, Solid Spandrel, Fixed Footing, Method II	Strip Concrete:  1. Remove concrete from midspan over length L_C with a concrete-stripping charge. 2. Attack both springing points with concrete-stripping charges: a. Against bottom face of arch ring. b. Or against top face (must remove fill beneath roadway to access arch ring)	1. Applies to arches greater than 35 meters 2. A one-stage attack should be adequate.
13		Arch, Open Spandrel, Fixed Footing, Method II	Strip Concrete:  Remove concrete from midspan over length L_C with a concrete-stripping charge.	A one-stage attack should be adequate.
14	Steel	Cantilever	Two Cuts: 1. Cut anchor span as closely to the pier as practical. 2. Cut midspan shear joints.	None
15		Cantilever and Suspended Span	One Cut:  Cut anchor span as closely to the pier as practical.	If demolition of the suspended span will create the desired obstacle, regard the span as simply supported and attack accordingly.

Table H-4. Attacks on continuous bridges (continued)

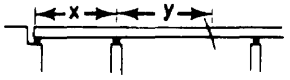
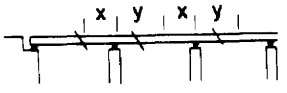
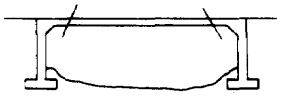
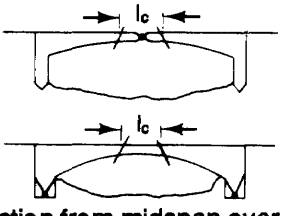
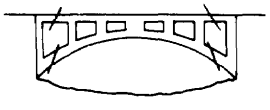
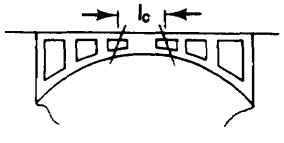
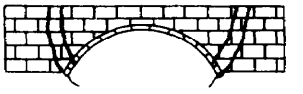
Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
16	Steel	Beam or Truss with Short Side Span	One Cut:  1. Cut interior span so *y* is greater than 1.25*x*. 2. If necessary, cut other interior spans as in Serial 17.	None
17		Beam or Truss without Short Side Span	Two or More Cuts:  Cut spans so *y* is greater than 1.25*x*.	None
18		Portal, Fixed Footing	Two Cuts:  Cut span twice, close to piers.	None
19		Portal, Pinned Footing	Two Cuts:  Remove section from midspan over length L_c.	None
20		Arch, Open Spandrel, Fixed Footing	Four Cuts: 	Angle cuts about 70 degrees
21		Arch, Open Spandrel, Pinned Footing	Two Cuts:  Remove section from midspan over length L_c.	None

Table H-4. Attacks on continuous bridges (continued)

Serial	Subcategory	Type	Attack Method	Remarks
a	b	c	d	e
22	Masonry	Arch, Method I	Two Cuts:  1. Cut at haunches. 2. Attack arch ring, spandrel walls, and parapet.	None
23		Arch, Method II	One Cut: Breach arch ring at crown.	None

Glossary

A total area

abatis Fallen-tree obstacles made by cutting trees that remain attached to their stumps.

ABCA American, British, Canadian, and Australian

AFV armored fighting vehicle

amatol A mixture of ammonium nitrate and trinitrotoluene (TNT); a substitute for TNT in bursting charges.

ammonium nitrate The least sensitive of the military explosives; it requires a booster charge to successfully initiate detonation; a component inmost cratering and ditching charges.

ammonium-nitrate satchel charge A mixture of ammonium-nitrate fertilizer and melted wax; the mixing ratio is 4 pounds of fertilizer to 1 pound of wax.

angled attack A method of attack used in bridge demolitions.

AT antitank

Attn attention

AP antipersonnel

approx approximately

ARNG Army National Guard

ASP ammunition supply point

AVLB armored vehicle launch bridge

beam collapse mechanism A method of allowing abridge to collapse under its own weight.

black powder The oldest-known explosive and propellant; a composite of potassium or sodium nitrate, charcoal, and sulfur.

blasting cap Used to detonate high explosives; there are two types: electric and nonelectric.

blasting machine Provides the electric impulse needed to initiate electric blasting-cap operations there are two models: M32 10-cap blasting machine and M34 50-cap blasting machine.

block demolition charge Prepackaged, high-explosive charges for general demolition operations, such as cutting, breaching, and cratering; composed of high-explosive TNT, tetrytol, Composition-C series, and ammonium nitrate.

block-hole method Away of removing boulders; a hole is drilled in the top of the boulder deep and wide enough to hold the required amount of explosive.

bottom attack Forms a hinge at the top of the span; as the span falls, the cut ends at the bottom move outward.

branch line A length of detonating cord.

breaching charges Used to destroy concrete-slab bridges, bridge beams, bridge piers, bridge abutments, and permanent field fortifications; the size, shape, placement, and tamping or confinement of breaching charges are critical to success.

breaching radius (R) For external charges, it is equal to the thickness of the target being breached; for internal charges placed in the center of the target's mass, R is one half the thickness of the target; for internal charges placed at less than half the mass thickness, R is the longer of the distances from the center of the charge to the outside surfaces of the target.

C *See* **tamping** factor **(C).**

C4 *See* **Composition C4 (C4).**

categorization To put into any of several fundamental and distinct classes to which entities or concepts belong; a division within a system of classification.

chg charge

class classification

classification (class) The systematic arrangement in groups based on the load-carrying capacity of bridges.

cm centimeter(s)

command post Located where the demolition guard can best control the defense of the demolition target from the friendly side.

common series circuit Used to connect two or more electric blasting caps to a single blasting machine.

Composition A3 A composite explosive containing 91 percent cyclonite (RDX) and 9 percent wax.

Composition B A composite explosive containing approximately 60 percent RDX, 39 percent TNT, and 1 percent wax.

Composition B4 A composite explosive containing 60 percent RDX, 39.5 percent TNT, and 0.5 percent calcium silicate.

Composition C4 (C4) A composite explosive containing 91 percent RDX and 9 percent nonexplosive plasticizers; it is effective in temperatures between -70 and + 170 degrees Fahrenheit but looses its plasticity in colder temperatures.

concrete-stripping charge Bulk, surface-placed charges designed to remove concrete from reinforced-concrete beams and slabs, exposing the steel reinforcement.

continuous bridge A bridge that does not fit the miscellaneous or simply supported bridge category.

cook off When blasting caps are detonated because of exposure to extreme heat.

counterforce charge A special breaching technique that is effective against rectangular masonry or concrete columns 4 feet thick or less.

cratering charge A calculated amount of explosives placed to create a crater.

cratering effect The cratering effect of high explosives depends on their total energy content, which determines the amount of energy available to throw the broken material from the crater. Because a shattering effect is not required to form a crater, low-velocity explosives are generally more effective for cratering purposes. Therefore, a relative effectiveness factor is not considered in determining the effect of a cratering charge. Blasting road craters or ditches normally requires large amounts of explosives. Because it is effective and inexpensive, an ammonium nitrate-based cratering charge is used as a standard cratering charge.

cross-section ditching method Used when it is necessary to blast the full width of the ditch in one operation.

cyclonite (RDX) A highly sensitive and very powerful military explosive; it forms the base charge in the M6 electric and M7 nonelectric blasting caps; when desensitized, it serves as a subbooster, booster, bursting charge, or demolition charge; used in composite explosives.

d required depth

D depth

DA Department of the Army

deliberate road crater A V-shaped crater approximately 7 to 8 feet deep and 25 to 30 feet wide with side slopes of 30 to 37 degrees; extends about 8 feet beyond the end boreholes.

demolition equipment set An assembly of tools necessary to perform demolition operations.

detonating cord Transmits a shock wave from the initiation set to the explosive charge; useful for underwater, underground, and above-ground blasting because the blasting cap of the initiation set does not have to be inserted directly into the charge.

detonating-cord priming Involves fewer blasting caps, makes priming and misfire investigation safer, and allows charges to be primed at State of Readiness 1 (Safe) when in placed on a reserved demolition.

diamond charge Used on high-carbon or alloy steel bars up to 12 inches in diameter or having a cross-sectional area of 12 square inches or less. *See also* **stress-wave method.**

direction of initiation The direction in which the shock wave travels through the explosive; may be parallel to the surface of the target or perpendicular to the target; determines the rate of energy transmitted to the target.

ditching charge A calculated amount of explosives placed to create a ditch.

DODIC Department of Defense identification code

dust initiator charge Uses small quantities of explosives with larger amounts of powdered materials to destroy thin-walled, wooden buildings or railroad boxcars; works best in an enclosed area with few windows.

dynamite *See* **standard dynamite, military dynamite.**

E total end clearance

E$_R$ required end clearance

elec electric

electric priming The insertion of an electric blasting cap directly into the charge.

end-priming method Priming explosives from the extreme end.

engr engineer

ENL enlisted

EOD explosive ordnance disposal

equip equipment

expedient flame fougasse Consists of a 55-gallon drum of thickened fuel, a kicker charge, a trip flare, and detonating cord; used in defensive and offensive operations for its incendiary, illuminating, and signaling effects.

explosives Substances that, through chemical reaction, violently change to a gaseous form. In doing so, they release pressure and heat equally in all directions. They are classified as low or high according to the detonating velocity or speed (in meters or feet per second) at which this change takes place and other characteristics such as their shattering effect. *See also* **low explosives** *and* **high explosives.**

external charge Placed on the surface of the target.

firing point Located as close to the target as safety allows; must protect the firing party from the effects of blast and falling debris; should be close to or collocated with the command post.

firing system The system placed between the initiation system and the charge.

firing wire The electric wire used between the initiation set and the electric blasting cap.

FM field manual

ft foot, feet

forty-pound, ammonium-nitrate block demolition charge A standard US Army munition consisting of 30 pounds of ammonium nitrate with a 10-pound TNT border.

fps foot/feet per second

GEMSS Ground Emplaced Mine Scattering System

GP general purpose

grapeshot charge Consists of a container, projectiles, buffer material, a charge, and a blasting cap.

H borehole depth

H depth, rise, height

hasty road crater Forms a V-shaped crater about 6 to 7 feet deep and 20 to 25 feet wide, extending approximately 8 feet beyond each end borehole. While it takes the least amount of time to construct, it is also the least effective barrier because of its depth and shape.

HE high explosive

HEAT high-explosive antitank (ammunition)

HEP high-explosive plastic

high explosives Change to a gaseous state almost instantaneously at 1,000 meters (3,280 feet) per second to 8,500 meters (27,888 feet) per second, producing a shattering effect on the target. Use high explosives when a shattering effect, or *brisance,* is required.

HQ headquarters

hydroscopic Material that readily takes up and retains moisture.

improvised cratering charge Consists of a mixture of ammonium nitrate fertilizer and diesel fuel, motor oil, or gasoline; the ratio of fertilizer and fuel is 25 pounds to 1 quart.

in inch(es)

internal charge Placed in boreholes in the target.

jamming Failure to completely collapse the span.

K *See* **material factor (K).**

kg kilogram(s)

kicker charge A l-pound charge of explosive placed high on a tree used to influence the direction of fall when employing timber charges.

kw kilowatt

L length

lb pound(s)

L_c required length of span removed

leapfrog series circuit Useful for firing any long line of charges; starts at one end of a row of charges and primes alternate charges to the opposite end and then primes the remaining charges on the return leg of the series; eliminates the need for along return lead from the far end of the line of charges.

lin line

line main Will fire multiple charges, but if a break in the line occurs, the detonating wave will stop at the break; use only when speed is essential and the risk of failure is acceptable.

low explosives Change from a solid to a gaseous state slowly over a sustained period (up to 400 meters or 1,300 feet per second). This characteristic makes them ideal when a pushing or shoving effect is required. Examples of low explosives are smokeless and black powders.

L_s average length of the bearing supports.

m meter(s)

mm millimeter(s)

Ml adhesive paste A sticky, putty-like substance that is used to attach charges to flat, overhead or vertical surfaces.

Ml detonating-cord clip A device for holding two strands of detonating cord together, either parallel or at right angles.

Ml military dynamite An RDX-based composite explosive containing no nitroglycerin; packaged in 1/2-pound, paraffin-coated, cylindrical paper cartridges that have a nominal diameter of 1.25 inches and a nominal length of 8 inches.

M10 universal explosive destructor A high-explosive charge in an assembled metal device; used to destroy ammunition and to convert loaded projectiles and bombs into improvised demolition charges.

M112 block demolition charge A l¼-pound block of C4 packed in a plastic envelope.

M118 block demolition charge A block of four 1/2-pound sheets of flexible explosive packed in a plastic envelope.

M180 demolition kit, cratering Consists of an M2A4 shaped charge, a modified M57 electrical firing device, a warhead, a rocket motor, a tripod, and a demolition circuit.

M183 demolition charge assembly Consists of 16 Ml 12 (C4) demolition blocks and 4 priming assemblies; is used primarily for breaching obstacles or demolishing structures when large demolition charges are required.

M186 roll demolition charge A 50-foot roll of sheet explosive.

M1A2 Bangalore-torpedo demolition kit Consists of 10 loading assemblies, 10 connecting sleeves, and 1 nose sleeve.

M1A4 priming adapter A plastic, hexagonal-shaped device, threaded to fit threaded cap wells.

M2 cap crimper Used to squeeze the shell of a nonelectric blasting cap around a time blasting fuse, standard coupling base, or detonating cord.

M51 blasting-cap test set A seIf-contained unit with a magneto-type impulse generator, an indicator lamp, a handle to activate the generator, and two binding posts for attaching firing leads; the set is waterproof and capable of operating at temperatures as low as -40 degrees Fahrenheit.

M60 weatherproof fuze igniter Used to ignite time blasting fuse in all weather conditions, even underwater, if properly waterproofed.

M700 time fuse A dark green cord, 0.2 inches in diameter, with a plastic cover; burns at approximately 40 seconds per foot.

M8 blasting cap holder A metal clip designed to attach a blasting cap to a sheet explosive.

max maximum

material factor (K) Represents the strength and hardness of the target material.

military demolition The destruction by fire, water, explosive, mechanical, or other means of area structures, facilities, or materials to accomplish a military objective. Demolitions are explosives used for such purposes. Demolitions have offensive and defensive uses. Examples are the removal of enemy barriers to facilitate the advance and the construction of friendly barriers to delay or restrict enemy movement.

military dynamite A composite explosive that contains 75 percent RDX, 15 percent TNT, and 10 percent desensitizers and plasticizers.

min minute(s), minimum

miscellaneous bridge Represents a small portion of bridge structures; examples include suspension, lift, and cable-stayed bridges.

mud-cap method Away of removing boulders in which the charge is placed in a crack or seam in the boulder and covered with 10 to 12 inches of mud or clay.

NA not applicable

NATO North Atlantic Treaty Organization

NCO noncommissioned officer

nitroglycerin Highly sensitive and extremely temperature-sensitive; the explosive base for commercial dynamites; not used in military explosives because of its sensitivity.

No. number

nonelectric priming The insertion of a nonelectric blasting cap directly into the charge.

NSN national stock number

obstacle folder Provides all the information necessary to complete a specific demolition operation.

Ohm's Law Defines the amount of voltage necessary to detonate the blasting caps.

oz ounce(s)

P weight of the explosive

pentaerythrite tetranitrate (PETN) A highly sensitive and very powerful military explosive; its explosive potential is comparable to RDX and nitroglycerin; insoluble in water.

pentolite (PETN-TNT) A mixture of PETN and TNT.

PETN *See* **pentaerythrite tetranitrate (PETN).**

PETN-TNT *See* **pentolite (PETN-TNT).**

platter charge Uses the Miznay-Shardin effect to turn a metal plate into a powerful, blunt-nosed projectile.

Plt platoon

pneumatic floats Airtight compartment of rubberized fabric inflated with air.

prac practice

pressure-sensitive adhesive tape Effective for holding charges to dry, clean wood, steel, or concrete; has better holding properties and is more easily and quickly applied than Ml adhesive paste.

QSTAG Quadripartite Standardization Agreement

qty quantity

R *See* **breaching radius (R).**

radial cracking. If the charge is large enough, the expanding gases can create a pressure load on the object that will cause cracking and therefore displace the material.

RDX cyclotrimethylenetrinitramine. *See also* **cyclonite (RDX).**

RE *See* **relative effectiveness (RE) factor.**

recon reconnaissance

reconnaissance order Specifies the objectives of the reconnaissance party commander.

relative effectiveness (RE) factor The amount of explosive used is adjusted by a relative effective (RE) factor which is based on the shattering effect of the explosive in relation to that of TNT. The shattering effect of a high explosive is related to its detonating velocity. For example, TNT with a detonating velocity of 6,900 meters per second has an RE factor of 1,00, while

Composition C4 with a detonating velocity of 8,040 meters per second has an RE factor of 1.34.

relieved-face crater A trapezoidal-shaped crater about 7 to 8 feet deep and 25 to 30 feet wide with unequal side slopes.

ribbon charge A special cutting charge used to cut flat, steel targets up to 3 inches thick.

ring charge A band of explosives completely circling the tree; it should be as wide as possible and up to 1-inch thick depending on the diameter of the tree.

ring main Will detonate an almost unlimited number of charges; preferred over the line main because the detonating wave approaches the branch lines from two directions.

rqr required

s borehole spacing

saddle charge A special cutting charge that uses the destructive effect of the cross fracture formed in the steel by the base of the charge; used on mild steel bars up to 8 square inches or 8 inches in diameter.

safety fuse Consists of black pow&r tightly wrapped with several layers of fiber and waterproofing material; burn rate varies with atmospheric and climatic conditions; burns significantly faster underwater.

satchel charge *See* **M183 demolition charge assembly.**

sec second(s)

see-saw collapse mechanism A method of allowing abridge to collapse under its own weight.

shaped charge Concentrates the energy of the explosion released on a small area, making a tubular or linear fracture in the target.

sheet explosive *See* **M118 block demolition charge.**

side-priming method A method of priming certain types of explosive, for example, dynamite and 40-pound cratering charge.

simply supported bridge Abridge in which the ends of each span rest on the supports; there are no intermediate supports.

single-line ditching method The most common ditching method; detonates a single row of charges along the centerline of the proposed ditch, leaving further widening for subsequent lines of charges.

shpd Shaped

snake-hole method Removing boulders by digging a hole large enough to hold the charge beneath the boulder.

SOP standing operating procedure

spalling Occurs when the charge's shock wave chips away at the surface of the object directly under the charge; if the charge is large enough, it will span the opposite side of the object.

springing charge A comparatively small charge for enlarging a borehole to accommodate a larger charge.

special cutting charge Uses considerably less explosive than conventional charges; however, it requires exact and careful target measurement to achieve optimal effect; examples include ribbon, saddle, and diamond charges.

STANAG Standardization Agreement

standard dynamite Does not include military dynamite; contains nitroglycerin plus varying combinations of absorbents, oxidizers, antacids, and freezing-point depressants.

State of Readiness 1 (safe) When the demolition charges are in place and secure; vertical and horizontal ring mains are installed but are not connected.

State of Readiness 2 (armed) When all charges and firing systems are complete and ready for detonation; all vertical and horizontal ring mains are connected.

stemming The process of packing material on top of an internal borehole or crater charge.

stress-wave method Employs the destructive effect of two colliding shock waves, which are produced by simultaneously detonating the charge from opposite ends.

supplementary adhesive Used to hold demolition charges when the target surface is below freezing, is wet, or is underwater.

T tracked

tamping Placing a calculated quantity of material on or around a charge to increase its effectiveness.

tamping factor (C) Depends on the charge location and materials used for tamping; do not consider a charge tamped with a solid material as fully tamped unless the charge is covered to a depth equal to or greater than the breaching radius.

tamping material Dirt, mud, sand, sandbags, water, or other available materials.

tetryl An effective booster charge in its noncomposite form and a bursting or demolition charge in composite forms; more sensitive and powerful than TNT.

tetrytol A composite explosive containing 75 percent tetryl and 25 percent TNT; the explosive component in demolition charges.

three-pin arch effect The result of an unsuccessful collapse mechanism.

time blasting fuse Transmits a delayed spit of flame to a nonelectric blasting cap; there are two types: M700 time fuse and safety fuse.

TNT *See* **trinitrotoluene (TNT).**

TNT block demolition charge Standard military munitions packaged in ¼-, ½-, and l-pound blocks.

TM technical manual

top attack Forms a hinge at the bottom; as the span falls, the cut ends at the top move outward.

TRADOC United States Army Training and Doctrine Command

trinitrotoluene (TNT) 'The most common military explosive; may be in a composite or noncomposite form; as a standard explosive, it is used to rate other military explosives.

US United States (of America)

USAR United States Army Reserve

v volt(s)

w required width

W wheeled

W_d required ditch width

x row spacing

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DEMOLITION RECONNAISSANCE RECORD

For use of this form see FM 5-250; the proponent agency is TRADOC.

SECTION I - GENERAL

1. FILE NO.			NAME AND RANK	ORGANIZATION
2. DEMOLITION RECON REPORT NO.		5 RECON ORDERED BY		
3. DATE	4. TIME	6 PARTY LEADER		

7. MAP INFORMATION

Name

Scale

Sheet No.

Series No.

8. TARGET AND LOCATION

9. TIME OBSERVED

10. COORDINATES

11. GENERAL DESCRIPTION: *(Attach sketches.)*

Type Construction	Other Data	Condition
☐ Earth	☐ Roadway Width _____	_____
☐ Timber	☐ Number of Bridge Spans _____	_____
☐ Concrete	☐ Number of Lanes _____	_____
☐ Asphalt	☐ Bridge Class: W- T-	_____
☐ Steel		

12. NATURE OF PROPOSED DEMOLITION *(Attach sketches.)*

13. UNUSUAL FEATURES OF SITE:

☐ High Tension ☐ _____

☐ Radar Installation ☐ _____

☐ Underwater Blasting ☐ _____

SECTION II - ESTIMATES

Determine availability of items 14, 15, and 16 before conducting reconnaissance.

14. MATERIAL REQUIRED	UNIT OF ISSUE	TYPE MISSION: CRATERING	CUTTING	OTHER/SPEC PURPOSE
Electric Caps	EA			
Nonelectric Caps	EA			
Detonating Cord	FT			
Time Fuse	FT			
Fuse Lighters	EA			
Firing Wire	FT			
Firing Device *(Specify type.)*	EA			
Explosive:				
TNT, 1/4-LB	EA			
TNT, 1/2-LB	EA			
TNT, 1-LB	EA			
TNT, 2 1/4-LB	EA			
(Other)				
(Other)				
Cratering:				
Cratering Charge, 40-LB	EA			
Shape Charge, 15-LB	EA			
Shape Charge, 40-LB	EA			
M180	EA			
Other Demolitions				

15. EQUIPMENT AND TRANSPORT REQUIRED *(Examples: trucks, ram sets and cartridges, demolition sets, post-hole diggers, nails, adhesives, tape, sandbags, and lumber.)*
NOTE: Troops may not ride in vehicles transporting explosives.

16. PERSONNEL AND TIME REQUIRED FOR:	NCOs	ENL	Time
a. Preparing and placing charges			
b. Arming and firing demolition			

17. TIME, LABOR, AND EQUIPMENT REQUIRED FOR BYPASS *(Specify location and method. Specify equipment to clear the site after demolition and the available bypasses that allow units to bypass the site.)*

18. REMARKS

DEMOLITION RECONNAISSANCE RECORD

Place additional comments in the appropriate blocks.

15. EQUIPMENT AND TRANSPORT REQUIRED (*Continued*)

17. TIME, LABOR, AND EQUIPMENT REQUIRED FOR BYPASS (*Continued*)

18. REMARKS (*Continued*)

19. ADDITIONAL COMMENTS (*Specify block.*)

FM 5-250
15 JUNE 1992

By Order of the Secretary of the Army:

GORDON R. SULLIVAN
General, United States Army
Chief of Staff

Official:

MILTON H. HAMILTON
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Washington, D.C., 30 January 1987

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HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, D.C., 30 November 1985

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1-2 blank	0	15-1 and 15-2	0
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5-1 thru 5-10	0	A-14 blank	0
6-1	1	B-1 and B-2	0
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Technical Manual

No. 9-1300-214

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC 20 September 1984

MILITARY EXPLOSIVES

REPORTING OF ERRORS

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail DA Form 2028 (Recommended Changes to Publications and Blank Forms) or DA Form 2028-2 located in the back of this manual direct to: Commander, US Army Armament, Munitions and Chemical Command, ATTN: AMSMC-MAY-T(D), Picatinny Arsenal, NJ 07806-5000.
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*This manual supersedes TM 9-1300-214, 28 November 1967, including all changes.

CHAPTER 1
INTRODUCTION

1-1. Purpose. This manual is intended for use as a text for instruction or as a reference source in the field of energetic materials. Only the materials of interest in conventional armaments are covered; nuclear armaments are not.

1-2. Scope. Chapter 2 is a history of the field of energetic materials. Chapter 3 divides the energetic materials field into three categories: explosives, propellants, and pyrotechnics. Chapter 4 discusses the principles of chemistry and physics pertinent to the energetic materials field. Chapter 5 is a description of the tests used to evaluate explosives. Both mandatory safety tests and tests used in the selection of particular compounds among the many explosive compounds are covered. Chapter 6 contains a description of the tests used to evaluate propellants. Chapter 7 presents detailed information about the compounds that are used by the United States as initiating explosives. A discussion of priming compositions is also included. Chapter 8 presents detailed information about the compounds that are used by the United States as booster and secondary explosives. Chapter 9 provides a discussion of those mixtures of materials that are used as propellants. Chapter 10 discusses the field of pyrotechnics. Foreign energetic materials are covered in Chapter 11. Safety and toxicity considerations are discussed in Chapter 12. Basic methods used to identify and detect energetic materials are presented in Chapter 13. Chapter 14 presents information pertinent to the packing, marking, storing, and shipping of energetic materials. Chapter 15 discusses disposal, destruction, decontamination, and demilitarization of energetic materials. Pertinent data on explosives and propellants are tabulated in Appendix A. Tables A-1 through A-8 allow rapid comparison of the important characteristics of the material. The bibliography is contained in Appendix B. An index for all material covered, referencing both paragraph and page numbers, concludes the contents of this manual.

CHAPTER 2
HISTORICAL DEVELOPMENT OF ENERGETIC MATERIAL

2-1. Introduction.

a. Purpose. This chapter describes the development of energetic material in chronological order.

b. Scope. This history is mainly concerned with military applications of energetic material, however some important nonmilitary uses are also discussed.

c. Relationship of Development to Science and Technology. Developments in the energetic material field are generally the result of a close relationship between basic research and technology. Advances in basic research provide new materials and new applications. The use of the new materials and new methods of application, as well as ideas from other fields, advance technology or even create new technology. The advancement of technology gives an impetus to further research. For example, the shaped charge effect was discovered in 1888. Little use of the principle was made until World War II, when technological advances made the tank a major battle weapon. At the present time, significant progress is being made in lessening the effect of a shaped charge on armor. This will require further development in energetic materials and their applications to defeat the newer types of armor.

d. Interrelationship Among Explosives, Ammunition, and Weapons.

(1) Explosives are the materials that detonate. They may be used independent of, or form a part of, ammunition. For military management purposes, the two are controlled as one category of weapons or armaments.

(2) Weapons are instruments of any kind used in fighting. We may consider weapons as the tools used in warfare. The development of these tools is the art or science of weaponry. Weaponry includes use of clubs, stones, slings, axes, spears, darts, javelins, bows and arrows, shields, body armor, etc. for hunting and fighting. Later, siege weapons such as catapults and ballista (the forerunners of cannon) were developed to hurl large stones and other missiles at fortifications. Better weapons created the need for a special group of artisans called metalworkers and metallurgists. The metalworkers began shaping the weapons from metals. The metallurgists practiced the art or science of extracting metals from their ores, refining them, and preparing them for use.

e. Discoveries, Inventions, Developments. Historians often disagree as to who was the first to discover, invent, develop, or use a new theory, characteristic, device, or material. Authenticating this information is a difficult task, for the records and terminology used to record these facts may be misleading. What has been published and used as an official source in subsequent documents may have been taken from an unreliable source. The history of energetic materials is particularly full of such examples. For example, who invented black powder or gunpowder? And, when was gunpowder first used? Sometimes the answer is that several or many people or nations were all involved at the same time.

2-2. Early Use of Flame, Incendiaries, and Smoke.

a. Flame and Incendiaries. Flame and incendiaries are the oldest chemical weapons dating back to the caveman's use of flames and burning coals to drive off animals and enemies. In Biblical times, armies attacking and defending fortified cities threw upon each other burning oils and flaming fireballs consisting of resin and straw. In 424 BC, the Spartans successfully employed a prototype of the flamethrower against a Greek fort in Delium. Attaching a pot filled with burning pitch, coals, and sulfur to a hollow log, they used bellows to blow a hot jet of flame which set fire to the city walls and routed the defenders. Incendiary compositions of pitch, sulfur, hemp or flax, and resinous wood were used in the Trojan Wars about 360 BC. Centuries later, the Romans used similar materials in fire bombs or fire pots, which they catapulted over the walls of besieged towns. To set fire to wooden forts they used hollow, perforated arrows filled with incendiary materials, which were ignited just before being shot. The most famous of the incendiary mixes was "Greek Fire," which was prepared by Kallinikos of Heliopolis in Syria to enable the Byzantine fleet to defeat the Caliphate Navy in 668 AD. The exact formula for Greek Fire is unknown. However, the formula is believed to be a mixture of sulfur, naptha, pitch, resin, and quicklime, which ignited and burned fiercely upon contact with water. The Greek Fire was apparently forced by water, under high pressure, through tubes or siphons. The violent reactions and high pressure ejected the burning incendiary mixture toward the enemy ships. For the next six centuries, the Byzantines used Greek Fire to thwart the Moslem and subsequent Russian sieges of Constantinople. Chinese

manuscripts as early as 969 AD mention fire arrows, fire lances, and incendiary "rockets." But with the exception of Greek Fire, such weapons had little impact on warfare until World War I.

b. Smoke. While history tells us that screening smoke was employed in early conflicts, the results of these isolated incidents were always too uncertain to justify the adoption of smoke as a recognized agent of warfare. In fact, prior to World War I dense clouds of smoke generated by the black powder used in battle had become a definite nuisance. These clouds obscured the field of vision, interfered with aiming and firing, and hampered the movement of troops. More recently, these very same characteristics have been exploited tactically by the planned employment of screening smoke munitions.

2-3. Invention of Fireworks and Black Powder.

a. Fireworks. Fireworks are devices that produce displays of lights, noise, or smoke by the combustion of explosive compositions. Fireworks are managed under that group of ammunition designated as "pyrotechnics." Those who ply this art are called "artificers." Some historians credit the Chinese with being the first true artificers. In the reign of Haiao Tsung of Nan Subng (1169-1189 AD), true fireworks made their debut. They were similar to those used today. The first fireworks were made of incendiary materials with various powdered minerals added to color, or to increase the light or smoke effect. Not until the invention of black powder were the artificers able to generate the displays with which we have become familiar today, such as Roman candles, rockets, fire crackers, serpentines, whistles, and stars. The French, in particular, became very adept at civil pyrotechnics by the 17th and 18th centuries. Civil pyrotechnics are generally limited to fireworks used for public display, signaling, or rescuing.

b. Black Powder. Authorities differ upon the origin of black powder accrediting in turn the Chinese, Hindus, and Arabs. In 1249 AD Roger Bacon, an English monk, recorded a formula for black powder saltpeter (7 parts), charcoal (4 parts), and sulfur (4 parts). Although Bacon was not the inventor, his were probably the first truly scientific experiments with this explosive. Sulfur and charcoal had been used in incendiary compositions for many centuries. Saltpeter (potassium nitrate) appears in nature but requires refining to supply the proper amount of oxygen to ignite the black powder mixture. Bacon's knowledge of purified saltpeter probably came from the Arabs who obtained this information from the Chinese about 1225 AD. Bacon mentioned in his writings that the ingredients of black powder were used in firecrackers made in various countries of the world.

2-4. Introduction of Gunpowder In Europe.

a. Invention of Guns and Gunpowder. The age of gunpowder began early in the 14th century with the invention of the gun, which consisted of a metal tube from which a projectile was discharged by the explosive force of black powder. Guns and gunpowder provided a new means of propelling stone, iron, or lead balls with greater force than catapults or slings. The discovery of the usefulness of black powder for accomplishing mechanical work may be considered the real beginning of the history of explosives. When ignited by a torch, a loose charge of black powder above the borehole of a gun served as a priming composition. A train of black powder in the borehole advanced the ignition to set off the propellant charge of black powder in the gun tube. The Chinese and Europeans evidently became aware of this application of black powder about the same time. Because Chinese developments did not keep pace with those in Europe, the Europeans have been credited with inventing and developing guns and gunpowder. The earliest mention of black powder on military supply lists was in 1326 AD. Also at that time, a Latin manuscript called "On the Duties of Kings," written by Walter de Milemete, King Edward Ill's chaplain, included the first known illustration of a cannon.

b. Manufacture of Gunpowder. Roger Bacon's black powder recipe was not for gunpowder. Different proportions of saltpeter, charcoal, and sulfur were required to propel missiles from the early cannon and firearms. In the mid 12th century, John Arderne, an Englishman, gave the proportions of saltpeter, charcoal, and sulfur as 6:2:1, the same as recommended by Marcus Graecus around 1275 and by Albertus Magnus in 1300. The Germans, who some scholars claim invented gunpowder and guns around 1313 (i.e., the legendary Berchtold Schwarz), were using a mixture of 4:1:1 in 1350. The ingredients were ground, mixed, and used in a fine powder or meal. At first, the materials were mixed in a mortar using a pestle operated by hand and were later mixed by horse power. Later, improvements in machinery mixed gunpowder with rollers on a marble slab and with wooden stamps. Mixing black powder was considered a highly technical art and a dangerous one too. Sometimes the final mixing was done at the gun site to reduce the hazard of stores exploding. Nevertheless,

the records of towns and armies during the early days of gunpowder contain many references to accidental explosions. Other mostly useless ingredients, such as amber, alcohol, camphor, wine, urine, arsenic, and sal armoniac, were added to the recipe to improve stability, reduce absorption of moisture, and to prevent crumbling. Depending on the weapon or the use, some countries varied the proportions of saltpeter, charcoal, and sulfur. For example, the French at one time made six different mixes one strong and one weak each for pistols, muskets, and cannons. Different mixes have been used for blasting, mining, and sporting weapons. In 1895, most countries, including the USA, adopted the English standard 75: 15: 10 (saltpeter: charcoal: sulfur), which had been in effect since 1781. This standard is generally used for all arms, the only difference being in the size of the grains.

2-5. Developments Between the 15th and 18th Century. The development of energetic materials from 1400 to 1800 were restricted mainly to improvements in the manufacture of black powder and related applications. By 1400, iron cannons, bound by iron hoops to keep them from bursting, and iron cannon balls were coming into use. At the end of the 14th century, a hand gun was invented that weighed 4.5 kilograms (10 lbs) and fired lead shot. One man carried the gun, which was mounted on a stand and aimed at the enemy. This weapon evolved into the arquebus or harqebus, a hand gun with a bent stock and a forked staff to support the barrel while firing. A lit match or fuse of serpentine black powder was used to ignite the propellant powder charge through a touch hole in the breech (closed end) of the gun barrel. Other important events or developments during this period are as follows:

a. *1425*. Corning, a new process for making black powder into grains instead of the finer serpentine gunpowder, was invented. Corning consisted of wetting black powder to form a paste, which was then pounded into a cake. The cake was broken into small lumps by hand and sifted. The resulting pieces, which were called corned powder, absorbed less moisture and were more suitable for use in cannons than the serpentine powder. Flame from the priming powder was distributed more efficiently by the larger grains. This resulted in a more complete explosion and reduced fouling.

b. *1540*. Standard gunpowder grain sizes for pistols, muskets, and cannons were adopted by the French. They discovered that less powder was needed to propel a projectile if the grain size was controlled. By using uniform, slow-burning grains they were able to control the pressure of the explosion in the gun, and thereby reduce the hazard of blowing up the gun. This discovery also led to improvements in gun design.

c. *1560*. Linen or paper bags containing gunpowder were used for charging cannons.

d. *1578*. An instrument for testing gunpowder was devised by Bourne of England. Until then, the only test was to burn a small quantity to see how much residue would be left. The testing device consisted of a small metal cylinder with a heavy metal lid on a hinge. The lid was prevented from falling by a ratchet, and the angle to which the lid rose when powder was fired inside the cylinder measured the strength.

e. *1588*. Explosive shells were used at the siege of Bergen op-Zoom and Wachtendonck, Holland by the Dutch. The shells were made from hollow iron balls filled with gunpowder. The gunpowder was ignited by a fuze consisting of a hollow tube filled with slow burning serpentine powder, and timed to burn 14 to 20 seconds, corresponding to ranges of 914 to 1830 meters (1000 to 2000 yards) for mortar fire. The knowledge for making this fuze was brought to the Dutch by an Italian deserter from Parma.

f. *1590*. Cartridges with ball and powder combined were introduced for small arms.

g. *1602-1604*. Fulminating gold, later used as a priming explosive, was invented by Johann Tholden, a Dutch chemist in the employ of the British Navy.

h. *1611-1632.* An improved paper cartridge was developed during the rule of Swedish King Gustavus Adolphus, thus increasing the rate of fire for firearms used in the Thirty Years' War.

i. *1613*. Blasting powder is reported to have been used in German mines to blast rocks. Less saltpeter and more charcoal and sulfur were used in blasting powder than in gunpowder.

j. *1627*. An improved instrument for testing black powder was devised by Curtenbach. This consisted of a heavy conical shot, which rested on the mouth of a small mortar and could travel vertically upwards along a stretched wire provided with a series of catches to stop the shot from falling.

k. *1627*. Black powder was used to blast ore in the royal mines at Schemnitz, Hungary following experiments by a Hungarian engineer, Kaspar Weindl. Using black powder for this purpose was slow to be accepted because saltpeter was expensive, boring instruments were not available, and safety hazards from mine gases and cave-ins were increased.

I. *1628*. Gold fulminate priming explosives for torpedoes were invented by J. Thollen for the British Navy.

m. *1647*. Testing the strength of gunpowder, by firing a ball from a mortar and measuring the distance the ball travelled, was proposed by Master-Gunner Nye in his "Art of Gunnery." This mortar test was adopted by France and other countries soon afterward.

n. *1654*. Ammonium nitrate was first prepared by J. R. Glauber, a German chemist.

o. *1679*. Blasting powder was used on a large scale in the construction of the Mal pas Tunnel, Canal de Midi, France.

p. *1684*. Glazing process for gunpowder was introduced. Rough gunpowder corns were glazed by tumbling them in large wooden drums until the grain surfaces were smooth. Graphite was added to coat the grains. Glazed gunpowder was less hygroscopic and flowed more easily than the unglazed gunpowder.

q. *1735*. Antimony sulfide and arsenic sulfide were used by Ruggieri of Italy in pyrotechnic mixtures for brilliant fireworks displays at Versailles.

r. *1738*. The closed bomb for measuring the pressure generated by gunpowder fired in a closed vessel was designed by d'Antony of Italy.

s. *1742*. The ballistic pendulum, which determined the velocity of a projectile's impact by measuring the recoil of a struck pendulum, was invented by Benjamin Robins, an English mathematician. Robins showed that air resistance on a moving projectile at high velocities is greater than the resistance at low velocities. Robins also developed the first practical chronograph, an instrument for measuring and recording short durations of time, and improved on a closed bomb for testing the power of an explosion.

t. *1771*. Picric acid was first prepared by Pierre Woulfe, a French chemist, by treating silk with nitric acid. Picric acid is an aromatic nitro compound which was used as a yellow dye until its explosive properties were discovered in 1871.

u. *1784-1788*. Potassium chlorate was prepared in its pure state by Claude L. Berthollet, a French chemist who discovered its detonating properties. His idea of using potassium chlorate instead of potassium nitrate in black powder was abandoned after a disastrous explosion during manufacture in 1788.

Berthollet also prepared fulminating silver in 1788.

v. *1784-1789*. Compact black powder grains were obtained by pressing the cakes with screw presses before corning at Faversham, England.

2-6. Nineteenth Century Development. Modern energetic materials technology began with the nineteenth century. New energetic materials began to displace the black powder formulas that had been the choice for use in weapons, ammunition, and blasting for over 350 years. The discovery of new materials or the practical application of previously known materials (fo example, picric acid) greatly influenced the design and performance of weapons and ammunition. In turn, the rapid development of weapons and ammunition, and the increased demands of new and expanding industries further accelerated the search for more effective, less expensive materials. During the nineteenth century, more powerful propellants (such as smokeless powder), better primers, various boosters or detonators, and new high explosives were introduced. There were significant advancements in the science and technology of weapons and ammunition, too. Among these were improved explosive (Congreve) rockets (later adapted for signaling and illumination), rifled arms, revolvers, magazine-loading rifles, machine guns, revolving turrets, armored naval vessels, percussion caps (encapsulated primers), metallic cartridges, time fuzes and impact fuzes for artillery shells, rifled breech-loading field artillery, obturation devices, and spring and hydropneumatic recoil mechanisms for artillery. Modern mass production began when Samuel Colt, an American gunsmith, first manufactured standard rifle and revolver parts. Mass production of small arms ammunition began when G. Moore Peters used the first cartridge-loading machinery at his factory in Ohio. Nineteenth century developments of energetic materials follow.

a. *1800*. Mercury fulminate was discovered by Edward Howard, an English chemist, who described its detonating properties in a paper before the Royal Society.

b. *1801*. Fireworks formulas containing metal salts and ammonium chloride were published by C. F. Ruggieri, an Italian artificer. These salts produced brighter flames because volatile metal chlorides were formed during the combustion reaction.

c. *1807*. The principle of using mercury fulminate as a primer was patented by Rev. Alexander J. Forsyth of Aberdeenshire, Scotland.

d. *1823*. Chlorates, discovered by C. F. Berthollet in 1786, were first used in fireworks by John Cutbush, an English artificer.

e. *1825*. Benzene, creosote, and naphthalene were isolated from coal tar (obtained from bituminous coal) by Rev. Dr. Clayton in England. Most of his products were later nitrated to produce explosives, such as trinitrobenzene and nitronaphthalenes.

f. *1826*. Aniline was first prepared by Unverdorben. Later, nitration of aniline resulted in the very powerful explosive called tetranitroaniline.

g. *1831*. Safety fuse for blasting was invented by William Bickford of Cornwall, England. The Bickford fuse consisted of a core of black powder tightly wrapped in textiles (mainly jute yarn). The timing, or burning time, for a given length of fuse was very accurate and consistent. This fuse soon replaced the less reliable fuses which were made of straws or quills filled with black powder, thus greatly reducing the hazard of accidental explosions in mining or construction. Later, the Bickford safety fuse was waterproofed by applying a coat of asphalt covered with either a textile or plastic.

h. *1832*. Ammonium perchlorate was first prepared by E. Mitscherlich, a German chemist, who also nitrated benzene and toluene in 1833 or 1834.

i. *1833*. Nitrostarch was discovered by Henri Braconnot, a French chemist, while dissolving starch in concentrated nitric acid to form a flammable nitric acid ester of starch. This is considered to be the beginning of modern high explosive technology.

j. *1837-1838*. Nitrated paper, soluble in ethyl alcohol, and nitrated cotton fibers, insoluble in ethyl alcohol, were prepared by Prof. Theophile Jules Pelouze, a French chemist. These products were highly combustible.

k. *1841*. Ammonium picrate was first prepared by Marchand, and was used in 1869 by Brugere as a propellant.

I. *1843*. Picric acid, discovered but not identified by Peter Woulfe in 1771, was rediscovered by A. Laurent who found that some of the salts were explosive.

m. *1845*. Guncotton was prepared by Christian F. Schoenbein, a German chemist, while at the University of Basel, Switzerland. Upon nitrating cotton with mixed nitric acid and sulfuric acid, he demonstrated that the resulting nitrocellulose was up to four times as powerful as black powder for blasting. The guncotton burned without leaving an ash. Schoenbein also prepared the first nitrosugar, which deflagrated suddenly and violently when heated to a certain point. Schoenbein and R. Boetter of Frankfurt, Germany, who had discovered guncotton independently, obtained patents in 1846 and 1847 under the title: "Improvement in Preparation of Cottonwool and Other Substances as Substitutes for Gunpowder." Serious accidental explosions during early attempts to manufacture guncotton in 1847 delayed its acceptance as an explosive; however, guncotton eventually became accepted universally for use in blasting and for smokeless powder when mixed with nitroglycerin.

n. *1846-1847*. Nitroglycerin, an ester of glycerin and nitric acid, was invented by Asconio Sobrero, an Italian chemist. Because nitroglycerin is very sensitive to slight shocks, commercial use was delayed until the invention of dynamite and blasting gelatin. Nitroglycerin was also used later to make smokeless powder.

o. *1847*. Mannitol hexanitrate or hexanitromannitol was first prepared by A. Sobrero, but the explosive properties were not examined until 1878 when N. K. Sokoloff of Russia investigated these characteristics.

p. *1847*. Cyanuric triazide was first prepared by Auguste A. T. Cahours, a French chemist.

q. *1850*. A testing device for measuring explosive pressure in cannons was developed by Col. George Bomford of the US Ordnance Department. Bomford inserted pistol barrels in holes drilled along the gun tube and measured velocities of bullet blowout. Based on these data, the weight of guns could be reduced.

r. *1850*. An improved testing device for measuring explosive pressures in cannons was designed by LTC Thomas J. Rodman of US Ordnance Department. Pistons with punch-type ends were installed at intervals on the cannon and were forced by the explosion of the propellant into copper blocks. Measuring the depth of the indentations indicated the relative pressures along the length of the gun tube. Rodman also developed a process of casting guns hollow and cooling them from within. The Rodman process put the metal surrounding the bore of the gun under a permanent compressive strain that greatly increased the gun's resistance to interior pressures.

s. *1853*. Nitroglycerin absorbed in magnesia was developed by V. F. Petrushevskii, a Russian officer, for use in mining gold in Siberia. This was a precursor of dynamite.

t. *1857-1858*. Sodium nitrate deposits found in Chile were originally converted to saltpeter (potassium nitrate) by reaction with potassium chloride, which was also in plentiful supply. Lammont du Pont, an American industrialist, introduced a new formula for black powder using sodium nitrate in lieu of potassium nitrate. Black powder containing potassium nitrate was called blasting powder A, and black powder containing sodium nitrate was called blasting powder B. Blasting powder B was less expensive and more hygroscopic, which made it more suitable for blasting. Powder formulas were considered more suitable for firearms, safety fuses, and fireworks.

u. *1858*. Diazo compounds were discovered by Peter Griess, who also prepared dinol or diazodinitrophenol.

v. *1859*. Ethylene oxide, ethylene glycol, and ethylene glycol ether were prepared by Charles A. Wurtz. A century later, ethylene oxide was used in fuelair explosives (FAX) developed by the US Armed Forces. Diethylene glycol was also developed simultaneously in 1859 by Wurtz and A. V. Laurenco.

w. *1860*. A caseless propellant, consisting of cakes of compressed black powder cakes or grains with perforations, was developed by T. J. Rodman while working at Frankford Arsenal, Philadelphia. This led to the use of grains shaped into hexagonal prisms about 2.54 cm (1 inch) long and 2.54 cm (1 inch) across. Perforations and grooves in the grains channel the flame from the explosion. As the grains burn inward from the prism surfaces and outward from the perforations, the burning gases flow continuously, thereby permitting the explosive energy to build up gradually until the maximum power is exerted as the projectile leaves the muzzle of the gun. This acceleration imparts a more efficient thrust to the projectile and extends the range of the gun.

x. *1861*. Guanidine was formed by the oxidation of guanine by Strecker. Guanine is a derivative of guano, which was formed from manure, especially that of birds and bats.

y. *1863*. Trinitrotoluene (TNT) was prepared by J. Willibrand, German scientist. Although TNT was used for many years in the dye industry, TNT was not used as an explosive until 1904. Thereafter, TNT became one of the most used high explosives.

z. *1862-1866*. Nitroglycerin production plants were designed for commercial applications by Alfred Bernard Nobel, a Swedish chemist, based on studies conducted with his father, Emmanuel, in 1859-61. In 1862, they built their first plant at Heleneborg, Sweden. Despite the tragic loss of his brother Emil in an explosion at that plant in 1864, Alfred erected two more plants in 1865 and another in 1866.

aa. *1865*. Magnesium was first used for pyrotechnics.

bb. *1865*. Nitrocellulose was purified by Sir Frederick A. Abel, an English chemist, who also successfully manufactured granulated nitrocotton. Abel pulped, washed, and compressed the nitrocellulose into blocks, sheets, discs, and cylinders, which were particularly useful for blasting.

cc. *1865*. Smokeless powder, used as a sporting propellant, was invented by Schultze, a Prussian officer, 2-6 through nitrating wood, washing the wood with a dilute solution of sodium carbonate, and drying.

dd. *1866-1867*. Dynamite was invented by A. Nobel by absorbing nitroglycerin (75) in kieselguhr (diatomaceous earth) (25). Kieselguhr, an inactive ingredient, stabilized the nitroglycerin, and made dynamite a much safer explosive to handle and use.

ee. *1867*. The fulminate blasting cap, a device consisting of mercury fulminate in a copper tube used to detonate explosives, was invented by A. Nobel. This cap was crimped to one end of a safety fuse (e.g. Bickford fuse), and then inserted into the dynamite cartridge.

ff. *1867*. Ammonium nitrate, pulverized and mixed with sawdust or charcoal, was proposed as an absorbant for nitroglycerin by J. H. Norribin and C. J. Ohlsson, Swedish inventors.

gg. *1868*. Dry compressed guncotton was detonated with a mercury fulminate detonator by E. A. Brown, an English chemist, who also discovered that wet guncotton could be exploded by the initiation of a small quantity of dry guncotton. This important discovery, on the principle of a booster explosive, led to the use of large blocks of wet guncotton in naval mines with comparative safety.

hh. *1869*. Dynamites with an active base were patented by A. Nobel. To create an active base dynamite, Nobel mixed nitroglycerin with combustibles (sawdust, charcoal, rosin, and starch), and oxidizers (sodium nitrate or potassium nitrate). This led to a more efficient explosive than guhr dynamite.

ii. *1870*. Ohlsson and Norribin's patent for ammonium nitrate dynamite was purchased by A. Nobel, who subsequently began production of ammonium nitrate dynamite.

jj. *1871*. Sprengel explosives, which consisted of mixing various combinations of oxidizing agents (chlorates, nitrates, and nitric acid) with combustibles (nitronaphthalene, benzene, and nitrobenzene), were patented by Hermann Sprengel, a German chemist. Oxidizing agents and liquid fuel were mixed on site before using.

kk. *1875*. The "Explosives Act" was passed by the British Government after a disastrous explosion at Birmingham killed 53 persons. The Explosives Act established Inspectors of Explosives, who were given the power to inspect all magazines and factories to ensure that operations were carried out in a reasonably safe manner. As a result, the number of deaths in explosives factories was greatly reduced. The provisions of this act have been adopted by many other countries.

ll. *1875*. Gelatinous dynamites and blasting gelatins were patented by A. Nobel.

mm. *1877*. Nitroguanidine was first prepared by Jousselin, but was not used in propellants until 1900.

nn. *1879*. Tetryl, a booster explosive, was first prepared by Michler and Meyer of Germany.

oo. *1879*. Ammonium nitrate gelatins, known as ammongelatins, were patented by A. Nobel.

pp. *1882*. Brownorcocoagunpowderwasmade by the Germans using partially burned charcoal from rye straw. The grains were made in single, perforated hexagonal or octagonal prisms. Brown powder was of higher quality, but was more sensitive to friction than black powder. The United States used brown powder during the Spanish-American War.

qq. *1883*. Tetryl was synthesized from picryl chloride and potassium methylnitramine by van Romburgh, a German chemist.

rr. *1883-1884*. Colloided rifle powder was prepared by Max von Duttenhofer by nitrating brown charcoal before mixing the ingredients. This brown powder was adopted by the German Army in 1884.

ss. *1884*. Smokeless powder, for military rifles, was invented by Paul Vieille of France. This powder was a completely colloided single-base nitrocellulose propellant. The French Army adopted Vieille's Poudre B. in 1866.

tt. *1884-1885*. High-speed photographic cameras were used for ballistic studies by Eugene Mach and P. Salcher of Austria.

uu. *1885*. Two flashless powders, ammonpulver and amidpulver, were patented and made by Gaens of Hamburg from ammonium nitrate, potassium nitrate, and charcoal.

vv. *1885*. The Hell Gate blast in New York Harbor used 34,000 kg (75,000 lbs) of dynamite, and 11,000 kg (24,000 lbs) of potassium chlorate soaked in nitrobenzene (rack-a-rock) to remove Flood Rock, a menace to navigation. This was the largest amount of explosives used in a single blast until then.

ww. *1885-1888*. Eugene Turpin, a French scientist, patented the process of melt-pouring picric acid into artillery shells as a high explosive filler. Sprengel had discovered that picric acid could be initiated by a powerful detonator, but had not exploited this knowledge. The French Government adopted a high explosive shell designed by Turpin using a picric acid filler. They designated the picric acid filler as melinite. In 1888, the British adopted picric acid, which they called lyddite as an high explosive filler.

xx. *1888*. The shaped charge effect was accidentally discovered by Charles E. Munroe, an American scientist, at the Naval Academy. Munroe discovered that a concave-shaped explosive charge pierces a steel plate.

yy. *1888*. Cyclotrimethylene trinitrosamine was discovered by Griess & Harrow and by Mayer, yet was not used until the Germans, who called it R-salz, used the composition in World War II.

zz. *1888*. Ballistite, the first double-base smokeless propellant, was prepared by Alfred Nobel by replacing camphor with nitroglycerin. In 1889, Nobel prepared ballistite from collodion cotton and nitroglycerin using a solventless method.

aaa. *1888-1889*. Cordite, the second successful double-base smokeless propellant, was prepared by Dr. W. Kellner in F. Abel's English laboratory. Sir James Dewar, British chemist and physicist, and Abel patented cordite for the British Government, which adopted cordite as a military propellant named Cordite Mark I or CSP (cordite smokeless powder).

bbb. *1890*. Tetranitrocarbazole, used in igniter and pyrotechnic compositions, was first prepared by Karl Graebe, a German chemist. The current method of preparation was developed in 1912 by the Leopold Cassella Company in Frankfurt, Germany, a division of the Interessen Gemeinschaft (I. G.) Farben corporation.

ccc. *1889-1890*. The development of explosive devices was greatly enhanced by the work of Theodor Curtius, German Nobel prize laureate, who discovered hydrazine in 1889 and hydrogen azide in 1890. He subsequently suggested to the German military the use of metal azides for primer application.

ddd. *1892*. Tetranitrooxanilide was prepared by A. G. Perkin, an English scientist, and used as a component in black powder type explosives and pyrotechnic compositions.

eee. *1894*. Butanetriol trinitrate, used a half century later as an explosive plasticizer for nitrocellulose, was first prepared by Wagner and Ginsberg.

fff. *1895*. Liquid oxygen explosive (LOX), carbon black packed in porous bags and dipped in liquid oxygen, was introduced by Karl P. G. von Linde of Germany. LOX was widely used by Germany during World War I, and in the United States Midwest for strip-mining in the 1950's.

ggg. *1896*. A layered smokeless propellant, which was prepared by glueing and compressing together several layers of different components, was patented by A. B. Bofors, Nobelkrut of Sweden. The outer layers were slow-burning, while the burning speed increased progressively towards the inner layers.

hhh. *1897-1898*. Cheddite, an explosive for blasting consisting of potassium chlorate or perchlorate mixed with a nitro compound and castor oil, was invented in England by E. Street. Cheddite derives its name from Chedde, France, where it was made.

iii. *1899*. Potassium dinitrobenzfuroxan, used in priming compositions, was first prepared by P. Von Drost.

jjj. *1899*. Cyclonite (RDX) was first prepared by Henning of Germany. Henning used RDX, which he called Hexogen, for medical purposes. The first to recognize the value of RDX as an explosive was E. Von Herz of Germany. The first to prepare RDX in quantity was G. C. Hale of Picatinny Arsenal, NJ, in 1925. However, it was not until World War II that the most important work in manufacturing processes and applications of RDX was done.

kkk. *1899*. Aluminized explosives, containing aluminum to increase the performance of explosives, were first proposed by R. Escales of Germany and were patented by G. Roth. Ammonal, their first, contained ammonium nitrate, charcoal, and aluminum.

2-7. Twentieth Century Development through World War I (WWI). This period saw the use of cordite smokeless powder and repeating rifles by the British during the Boer War (1899-1902) in South Africa; large scale naval battles and full-scale use of machine guns in the Russo-Japanese War (1904-1905); and the introduction of submarine warfare, armored tanks, aerial bombing of civilians by dirigibles, and strafing and bombing by aircraft during World War 1 (1914-1918). World War I saw concentrated machine gun fire, artillery barrages, firing long ranges from railroad guns and from large guns on battleships, firing torpedoes, laying mines, using depth charges in anti-submarine warfare, and signaling and illuminating with flares. Soldiers were issued steel helmets and gas masks for individual protection.

a. 1900. Cordite smokeless powder, used by the British in the Boer War, caused excessive corrosion in gun barrels. As a result, the formula for cordite was changed to reduce the amount of nitroglycerin from 58% to 300/0 and to increase the amount of nitrocellulose to 65% with the amount of mineral jelly remaining at 5%.

b. 1900. Picric acid (British lyddite) shells were used in the Boer War but did not detonate completely. This was attributed to faulty construction of the detonators.

c. 1900. The Contact Process for manufacturing concentrated sulfuric acid and oleum was discovered by Badische Anilin-und Sodafabrik of Germany. This process was less expensive than the chamber method previously used. As such acid was required for mixed nitric-sulfuric acid to nitrate aromatic hydrocarbons to polysubstitution, trinitrobenzene and trinitrotoluene (TNT) could be inexpensively manufactured.

d. 1900. Chromatography, a physical method of separation in which the components are partitioned between two phases, was invented simultaneously and independently by American geologist D. T. Day and Russian botanist M. S. Tsvet. The qualitative method of separation of ingredients by adsorption was known for centuries.

e. 1900. Regular-delay electric blasting caps for rotational shooting (0.5 to 12 seconds) developed.

f. 1901-1904. A trinitrotoluene (TNT) manufacturing process consisting of three phases was developed by C. Haussermann of Germany. This method, which proved to be more economical than direct nitration of toluene to TNT, was used in the United States until World War II. The German industry adopted this process in 1902, when they adopted TNT as the filler for high explosive shells. They also used TNT for demolition purposes, replacing picric acid.

g. 1902. Detonating cord, developed in France, was improved, leading to adoption in the United States by the Ensign-Bickford Company in 1912.

h. 1902. Antifreeze for dynamite was researched extensively in many countries following a disastrous explosion during defrosting dynamite in Greisnau, Germany. The problem of producing a satisfactory antifreeze remained unsolved until S. Nauckhoff of Sweden published his work in 1905, listing requirements for a satisfactory antifreeze, and compounds which met these requirements.

i. 1903. A muzzle-flash suppressor using vaseline with 1-2% sodium bicarbonate was proposed by Rottweil Fabrik of Germany. This was replaced in 1905 by soap or rosin.

j. 1904. The Obermueller Stability Test, which consisted of heating 1-2 grams of nitrocellulose in a small tube under vacuum at 135-140° and measuring the pressure of evolved gas by vacuum manometer, was introduced.

k. 1904-1905. Methyl picrate (2,4,6trinitroanisole) was patented for use in smokeless propellants. The powder consisted of an equal amount of methylpicrate and pyrocellulose.

l. *1905*. Nitrostarch was produced in a stable form. Nitrostarch is similar to nitrocellulose but is lower in strength. Nitrostarch does not cause headaches from skin contact as do TNT, nitroglycerin, dynamite, and many other explosives.

m. *1906*. Various substituted ureas, called centralites and akardites, were developed at the Central Laboratory for Scientific and Technical Research at Neubabelsberg, Germany, for chemical stabilizer application in smokeless powders.

n. *1906*. Lead azide was proposed by Col.

A. A. Solonina of Russia for use in compound detonators (initiating explosives) in lieu of mercuric fulminate.

o. *1906*. Hexanitroazobenzene was prepared by E. Grandmougin and H. Lehmann of France, and recommended by Tenny L. Davis for use in boosters.

p. *1907*. Diphenylamine, designated as poudre B, was approved as a stabilizer for French naval cannon propellants and other large caliber guns. This stabilizer replaced amyl alcohol after the disastrous explosion in 1907 of the battleship lena.

q. *1907*. Mixed glycol esters, such as dinitroacetin with dinitroformin, were patented as dynamite antifreeze by Vezio Vender of Italy.

r. *1908*. A detonating cord (cordeau detonant) containing TNT instead of blackpowder was patented in France. This detonating cord had a detonation velocity of 4,880 meters (16,000 feet) per second.

s. *1909*. Ammonium picrate (Dunnite or Explosive D) was standardized in the United States as a bursting charge for armor-piercing (AP) shells. These AP projectiles could be fired through 12 inches of armor plate, and could be detonated on the far side by an insensitive primer.

t. *1909*. Low-nitrated aromatic hydrocarbons, because of their stability and insensitivity to shock and to ignition, began to be used in coal mining explosives compositions.

u. *1909*. Solventless powder (or propellant) was discovered by Brunswig and Thieme of Germany, although many others contributed to the development of such propellants.

v. *1910*. Preparation of 2,3,4,6-tetranitroaniline, a powerful explosive, was patented by Flurscheim. This explosive was used during World War II by the Germans and Japanese.

w. *1910*. Tetracene was first prepared by K. A. Hofmann in Germany. More extensive studies of the compound were conducted in 1931 by Rinkenbach and Burton.

x. *1910-1913*. Laminated solventless propellants were prepared by Dr. C. Claessen, a German scientist. Making propellants into large solventless grains was less time consuming than making solvent propellants.

y. *1912*. TNT was adopted as the standard bursting charge in high explosive shells for the field artillery of the US Army.

z. *1912*. Nitroisobutylglycerol trinitrate or trimethylol nitromethane trinitrate, used as an explosive gelatinizer for nitrocellulose, was first prepared by Hofwimmer.

aa. *1912-1913*. Tetranitroaniline (TNA) was patented by Dr. B. J. Flurscheim, an English scientist.

bb. *1914*. Lead styphnate (trinitroresorcinol), an initiating explosive, was first prepared by E. von Herz of Germany. Col. A. A. Solonina of Russia was the first to propose using lead styphnate in compound detonators.

cc. World War I. The high-explosive technology of the contending powers greatly influenced the conduct of World War I. At the outbreak of war in the summer of 1914, the German General Staff had planned to fight a high-explosives war of great intensity. Their plan was to mount a sudden and overwhelming attack using vast stores of artillery ammunition accumulated over the preceding forty years. After the battle of the Marne in 1914, the Germans realized that explosives production must be expanded; and they turned to their dye industry for this expansion. When the war began, Germany's chemical industry was producing 85% of the world's dyes. The Germans were able to rapidly convert their plants to production of synthetic ammonia, nitric acid, and sulfuric acid, which were required for the manufacture of explosives and chemical warfare agents. When Germany's access to Chilean saltpeter was cut off by the Allied blockade, the key to the German war production of explosives was the Haber process for producing ammonia from atmospheric nitrogen. By expanding their nitrogen plants at Oppau and Merseburg, Germany was able to become independent of foreign countries for the supply of ammonia and nitric acid. Because these chemicals were so essential for the manufacture of explosives and fertilizer for food products, it is doubtful if Germany could have continued the war beyond 1916 without the amazing speed with which the I. G. Farben concern was able to convert their dye plants to explosives plants. For example, at Leverkusen, a TNT plant producing 250 tons per month was put into operation in six weeks. The major powers began accelerating the search for substitutes or supplements to TNT. The most important were mixtures of high explosives, such as TNT, TNX, and TNN, with ammonium nitrate and aluminum. By 1914, the French had already begun

replacing picric acid (melanite) with TNT. In 1915, the British developed amatol (TNT plus ammonium nitrate) to extend the supply of TNT. In 1917, Austrian ammonal T (TNT, aluminum, and ammonium nitrate) was developed by R. Forg to be used in underwater explosives, such as torpedoes and depth charges. Lead azide was introduced as an initiator, and tetryl was used as a booster explosive for artillery shell charges. About 2,500,000 tons of high explosives were used by the contending powers during the war, resulting in an estimated 10 million casualties.

dd. *World War I*. High-explosive aerial bombs were first dropped from German Zeppelins during the 31 May 1915 raid on London. The Germans continued to use these dirigibles, practically unopposed, in their air raids on London and Paris until late in 1916. Then the British and French began to counter these attacks with anti-aircraft gunfire and fighter aircraft. Soon the Germans began using their large Gotha bombers, which they employed throughout 1917 and 1918. In retaliation, the Allies began producing fleets of larger bombers and various high-explosive bombs.

ee. *World War I*. Incendiary bombs were also first used during the German Zeppelin raid over London on 31 May 1915, when one dirigible dropped 90 incendiary bombs. The early incendiaries used by the Germans in their air raids over London and Paris were made from a mixture containing manganese dioxide and magnesium. Later, the French used sulfur-bound thermite, a mixture of iron oxide and powdered aluminum, in an incendiary drop bomb. The British were the first to develop incendiary bomb clusters, which could release either 144 or 272 bomblets. A De Haviland bomber could dispense up to 860 of these 6.5 oz incendiary bomblets, and a Handley-Page V bomber could dispense up to 16,000. By flying in formation, these bombers could cover a large area with a blanket of burning incendiary materials.

ff. *World War I*. Flamethrowers were first introduced by the Germans on the French front on 25 June 1915. Their weapon was a cylindrical steel vessel about 61 centimeters (2 feet) high and 38 centimeters (15 inches) in diameter, fitted with carrying straps. Internally, the cylinder was divided into a compression chamber and an air reservoir. A short hose carried the fuel to the nozzle where it was ignited. The propellant was nitrogen. The fiery spurt of burning oil, the roar of the flame, and the billowing clouds of black smoke had a terrifying effect on troops in trenches. Using this prototype of the modern portable flamethrower, the Germans drove back a British rifle brigade from trenches near Ypres, Belgium, in 1915. The Americans used a heavy viscous tar and a more fluid, flammable liquid such as crude benzene for their flame fuel mixture. A hydrogen pilot lamp at the flamethrower nozzle was used to ignite the flame fuel. The World War I flamethrowers had a range of about 30 meters. Although effective for assaulting fortifications, the flamethrower was also very hazardous for the operator because of its short range.

gg. *World War I*. Smoke munitions were used both on land and sea by the belligerent powers in World War I. In July 1915, the British were the first to use smoke pots, which were filled with pitch, tallow, black powder, and potassium nitrate. The first large-scale smoke operation occured on 20 September 1915, when the Canadians fired several thousand smoke shells from trench mortars during the attack against Messines Ridge. Although very successful against the Germans, the British and French tanks of World War I were capable of travelling only four miles per hour, which made them very vulnerable to artillery fire. The British Tank attack at Cambrai on 20 November 1917 was supported by intense artillery smoke shelling, which enabled 350 tanks to break through the German lines. On 15 June 1918, the Austrians used smoke to screen their crossing of the Piave River, from Vidor into San Giovanni, from Italian machine gun concentrations. The Allies generally used white phosphorus (WP) to fill their smoke shells; whereas the Germans, because of a shortage of phosphorus, used a mixture of sulfur trioxide in a chlorosulfonic acid solution. The Germans used this type of smoke (FS) to successfully screen their warships during the battle of Jutland in 1916. Later, the United States adopted FS smoke for use in spotting rounds, for liquid chemical agent shots, and in airplane smoke tanks. FS was reclassified obsolete in November 1975 because WP was considered better for marking targets and FS droplets from aerial spray destroyed the nylon fabric in parachutes. Titanium tetrachloride (FM) was also used as a filler for spotting rounds during both world wars, but was removed from the US inventory because of its high cost. In 1918, tanks carried containers filled with chemicals, which when injected into the vehicle exhaust system formed a cloud of screening smoke. Sulfuric acid, chlorosulfonic acid, oleum, and crude oil were used as the smoke screening agent in these early smoke generators. WP hand and rifle grenades were used by the infantry for screening movements. The main disadvantage was the danger of the user being exposed to falling particles of burning white phosphorus, which is also an incendiary. WP grenades were reclassified obsolete in November 1975 by the US Army.

hh. *World War I*. Incendiary artillery shells and rifle bullets were introduced in 1915 to set fire to buildings, supply dumps, and enemy observation balloons. The Germans used sodium in their 17.5 centimeter artillery shells. They also used thermite or an aluminum-thermite mixture in their other artillery rounds. The Allies used thermite most frequently. Thermite incendiary grenades were issued to raiding parties for hasty destruction of captured enemy weapons that could not be retrieved.

ii. *World War I*. Pyrotechnics for battlefield illumination were used extensively during World War I. The British alone used 10 million position light flares per month. The art of making illuminants had been neglected after the reign of Louis XIV until the twentieth century. In 1913, the German Krupp Works developed an illuminating projectile, which they called a searchlight shell and which later became known as the star shell. The first star shell contained six small tubes, called stars, loaded with an illuminating composition. The mixture used was similar to that in the white Bengal lights for fireworks displays; but ribbons of magnesium were substituted for antimony powder. A folded parachute was placed in the bottom of each tube. The projectile was fired from a cannon or mortar. When the projectile reached a height of 300 meters, a mechanical time fuze set off a small black powder charge releasing the tubes from the shell and igniting the pyrotechnic mixture. Springs were used to open the parachute instantly, and the tube with its burning star floated slowly to earth. The illuminating material burned very brightly for 45 seconds to several minutes depending upon the model. The French constructed a similar projectile containing eight cylinders, which was fired from their 155 millimeter howitzer. However, they preferred using burning-type fuses to set off the powder charge in their star shells. Later, the Germans replaced the star tubes with a six-sided prism, which was more compact and could be adapted for use with rifles, special pistols, and large caliber carbines. By using plates to retard the fall of the star, more space was made available in the star for storing the illuminating mixture; and a light of greater intensity or longer duration was obtained. The Italians used a hand-held, heavy pasteboard tube to discharge a sheet-iron star shell tube, which expelled its illuminating parachute flare. This flare burned about 40 seconds. Many different illuminating devices were developed and used by both sides, but perhaps the simplest and most useful for trench warfare was the illuminating grenade. Thus every soldier on night patrol had his own device for lighting his sector, and exposing the advancing enemy to aimed gunfire.

jj. *World War I*. During World War I, pyrotechnics for signaling included colored smoke cartridges, canTM 91300-214 dies, flares, streamers or trails, star signals, and night signals. Four general designs of firework devices were in constant use by the French and the British armies. These devices were Very-type signal pistols, rifle lights, rockets, and ground or position signals (e.g. candles). (The same type of devices were used for illumination.) The signal-pistol cartridges used by the French were fitted with delay fuzes, which effected the ignition when the projectile reached its maximum height. Some realization of the development in pyrotechnic construction due to the war may be had by considering the latest production of the French 35-millimeter signal cartridge, which included 14 varieties or combinations of signals. Upon entering the war, the United States adopted many of the French signals for Army use. This was mainly because the American forces were to operate in the French sector, which necessitated an identical system of signals. Generally, the fireworks and devices employed by the Germans were similiar to those of the French, but there was an important difference in the method of construction for the signal-pistol cartridge. The German cartridge was ignited just after emerging from the barrel of the pistol. Rockets mounted on sticks for stabilization during flight were employed by the Allies. The Germans followed Congreve's construction in the use of metal, but modified the design to eliminate the use of a stick. In the German rocket, the openings for escaping gas were in the base. Before the outbreak of the war, the art of pyrotechny had reached such a point that little difficulty was encountered in securing adequate mixtures for the various colors required in signaling. Different colored flares had been used for many years commercially. The railroad companies regularly employed pyrotechnic devices, such as red railroad fusee, while blue light pyrotechnics were used for signaling at sea. The colors used by the Allies included red, green, yellow, blue, black, various numbers of white stars, and changing colors. The Italians used a tri-color parachute flare, which emitted red, white, and green colors. The Italians also developed a hissing flare, which, when suspended from a parachute, burned with a hissing noise audible over an area of 3,000 meters (3,284 yards) in diameter. This was found particularly effective as a gas alarm. Some of the ingredients used in the WW I pyrotechnics were aluminum, potassium nitrate, sulfur, antimony sulfide, antimony metal, dextrine, meal powder, barium chlorate, potassium chlorate, fine charcoal, barium nitrate, red gum, paris green, shellac, sodium oxalate, magnesium carbonate, strontium carbonate, calomel, copper oxychloride, calcium carbonate, sawdust and grease mixture, sugar, lamp black, ultramarine blue, paranitraniline red, lactose, auramine, chrysoidin, synthetic indigo, phosphorus, paraffin, and arsenic.

2-8. Developments after World War I through World War II. The most complicated task confronting the US Army Ordnance Department at the end of World War I lay in the field of ammunition. Combat experience had shown the inadequacies of the ammunition used in 1917-1918, which were inaccuracies, failures, lack of safety features, and a host of needless complexities. But whereas the combat arms could specify exactly what the gun and vehicle requirements should be, their recommendations for the development of explosives, propellants, projectiles, and fuzes had to be couched in general terms. Here were basic research problems that ammunition experts had to define. Often they sought interim solutions, and waited until greater knowledge could supply better answers. Hence the ammunition designers had free reign within budgetary limits. Over the 20 years between the two world wars, the Army dedicated more money to the ammunition program than to any other development work. During these two decades, RDX, PETN, EDNA, DEGN, lead styphnate, and dextrinated lead azide were developed as military explosives. The development in the United States of processes for producing toluene from petroleum removed limitations on the availability of TNT, and permitted development of the powerful and castable explosives like composition B and pentolite. Flashless propellants were developed in the United States, and lowerosion DEGN propellants were developed in Germany and Italy. Diazodinitrophenol was developed as an initiator in the United States, and tetracene was developed in Germany as a new explosive ingredient of priming compositions. World War 11 (1939-1945) saw the development of rocket propellants based on nitrocellulose-nitroglycerin or nitrocellulose-DEG N mixtures, and the use of nitroguanidine in artillery propellants. New special-purpose binary explosives, such as tetrytol and picratol, were developed for use in demolitions, chemical bombs, and semi-armor-piercing bombs. A number of plastic explosives used for demolition work were developed in Great Britain and the United States, the most important being the C-3 composition based on RDX. The discovery and great value of the blast effect of explosives led to the development of tritonal, torpex, and minol, which contain powdered aluminum and have powerful blast effects. In the spring of 1943, EDNA or haleite was adopted for testing purposes after the DuPont Company, while under contract, overcame the problem of manufacturing ethylene urea, one of haleite's intermediates. But it was not until the end of the war that production of haleite could get started. Incendiaries were found to be even more effective than high-blast explosives in the destruction of cities. By using improved fire bombs filled with thickened or gelatinized incendiary oil or gasoline mixtures, and large clusters of incendiary bomblets filled with thermate (an improvement of the WW I thermite), the US air forces were able to literally set fire to cities like Dresden and Tokyo. Flamethrowers and smoke munitions were used extensively by both sides. Finally, the extensive use of armor during the war led to the development of anti-tank weapons, armor-piercing shells, and shapedcharge munitions. The application of the shaped-charge principle resulted in the use of special explosives of the pentolite type.

a. *1918-1939*. Ammunition research in the first postwar years was inspired not only by new requirements, but also by the problems encountered in preserving ammunition, especially propellants, stored after the Armistice. Research proceeded in three areas: determining the stability of smokeless powder, studying the effects of long term storage on stability, and creating more efficient methods of drying. A good deal of valuable information on these substances was assembled at Picatinny Arsenal, NJ, before 1926, notably that on feasibility of the vapor method of drying, which reduced drying time from months or weeks to days. But a more permanent solution of some phases of the powder storage problem would be to develop new non-hygroscopic powders, which because of their chemical composition would not absorb enough moisture to affect their ballistics or chemical stability even when stored in a damp atmosphere. If, at the same time, flashless and smokeless qualities could be incorporated, the advantages would be even greater. Thus the search for flashless non-hygroscopic (FNH) powders was vigorously pushed. The DuPont Company, under a special agreement with the Ordnance Department, followed one route of investigation, while Picatinny Arsenal followed another. Each achieved considerable success. The peacetime development of complete single-base and double-base non-hygroscopic powders, flashless in many weapons, was one of the most useful accomplishments of the Ordnance Department before 1940. Traditionally, British propellants have been of the double-base type developed prior to World War II and designated as cordites. The cordites were made up of varying percentages of nitrocellulose, nitroglycerin, and mineral jelly. The mineral jelly (petroleum jelly or petrolatum) acted as a stabilizer. A sample of British MD cordite has been found to be of apparently unchanged stability after 30 years of temperature-climate storage.

The search for a compound that was both smokeless and flashless had its beginning in the requirement established by the US Army Ordnance's Westervelt Board in 1919. In the early 1920's, ordnance scientists offered the using arms samples of nitroguanidine, which to a degree unobtainable in any other known propellant, had both properties. But nitroguanidine gave off such noxious ammoniacal fumes in combustion that the Field Artillery vetoed its use. The Ordnance Department, with no customers in prospect, then abandoned all thought of building plants to make nitroguanidine. But ammunition specialists found no satisfactory substitutes. Adding potassium sulfate to propellants for antiaircraft fire, where flashlessness was all important, helped to solve that problem. However, it was no answer to the demand for a completely smokeless and flashless propellant for field artillery where smoke would obscure a gunner's vision and muzzle flash would reveal the tank or battery position.

b. *1918-1939*. Between the two world wars very little was done in the United States to develop the art of rocketry and rocket propellants. A golden opportunity to assume leadership in this field was missed when just before the Armistice in 1918, Dr. Robert H. Goddard, Professor of Physics at Clark University, demonstrated a shoulder-fired "recoilless gun" or "rocket gun" at Aberdeen Proving Ground, MD. The results of Dr. Goddard's demonstration were summarized by Ordnance Department witnesses as proving the validity of his concept of modern rocketry. However, the lack of suitable powder and the need for further work on the electrical firing mechanism along with the Armistice led the Ordnance Department to shelve the project. Goddard died without receiving any acclaim for this pioneering work, although comparison of his rocket gun with the bazooka adopted 24 years later shows how closely the 1918 model resembles the later weapon. During the 1920's, metriol trinitrate or trimethylolethane trinitrate, used as an ingredient in rocket propellants in World War II, was prepared in Italy and Germany. In 1931, the US Army created a one-man rocket unit by assigning Captain Leslie A. Skinner to study the possible use of rockets. Skinner was handicapped by limited funds for research, and by the indifference of superiors. During the mid-thirties, the British began more intensive research on anti-aircraft rockets in anticipation of massive bomber air raids upon their cities. In the meantime, the Germans made great strides in the development of rockets and missiles and the attendant propellants. This was especially due to the work of Wernher von Braun in the late 1930's.

c. *1920*. Cardox, a device for breaking coal in gaseous mines by the pressure produced on heating liquefied carbon dioxide, was developed. Similar devices were developed in the United States in 1930, and were improved upon in 1955 (Hydrox) and 1959 (Chemecol).

d. 1927. Diethyleneglycol dinitrate was thoroughly examined by W. H. Rinkenbach, and the current method of preparation was patented in 1928 by A. Hough.

e. *1930-1931*. Dextrinated lead azide was adopted for use by the US Army, and began replacing mercuric fulminate in priming compositions.

f. *1931*. 2,4-dinitrotoluene (2,4-DNT), obtained earlier as an impurity in crude TNT, was used in some explosive mixtures.

g. *1935*. From the 1920's onward, scientists at Picatinny Arsenal had been trying to find a compound that would have the high brisance of RDX without the sensitivity to friction and impact. Research on this problem, principally by Dr.George C. Hale, chief chemist, led to the discovery of ethylenedinitramine (EDNA or haleite) the first entirely American high explosive. More powerful than TNT, EDNA was slightly less powerful then RDX but was also less sensitive. EDNA's stability gave it an important advantage in considerations of manufacturing, loading, storage, transportation, and field use. Designated haleite, in honor of Dr. Hale, this new explosive could be press-loaded into small shells without a desensitizing agent, and its derivative, ednatol, a mixture containing 42 percent TNT, could be melt-loaded into large shells as easily as amatol. These advantages were offset in prewar days by the high manufacturing cost of one of its intermediates, ethylene urea. Delay in solving manufacturing problems prevented haleite from getting into combat in World War II.

h. *1936*. Primacord, based on a French patent, was developed by the Ensign-Bickford Company, CT.

Primacord consisted of PETN covered with textiles, waterproofing material, and plastics. This detonating cord had a velocity of 6,405 meters (21,000 feet) per second, and has been used extensively by the armed forces for demolition work.

i. *1937*. Baratol, a mixture of barium nitrate and TNT, was developed by the British and used extensively in WW II.

j. World War II. High Explosive Bombs. When World War II began in September 1939, the standard United States filler for high explosive bombs was trinitrotoluene (TNT). On 5 June 1940, the United States released 8,000 metric tons (9,000 short tons) of TNT to the British under Lend Lease. This came out of a manufacturing surplus of only about 9,000 metric tons (10,000 short tons). Most of the war was fought by the United States with bombs standardized in 1941.The earliest departure from TNT for the fillings was RDX, an explosive known for its great power and brisance but generally considered too sensitive. The British had developed a method of using beeswax to desensitize the RDX, and used this filler with terrible effect in the 2-ton "blockbuster" bombs dropped on Berlin in April 1941. During the following summer, Air Marshall Arthur Harris had pressed for large-scale production of RDX in America. The United States Navy was also interested in the explosive because of its effectiveness under water, especially in ; ,nixture with TNT and aluminum called torpex. But the United States Ordnance Department, while willing to start production for the British and the Navy, held back until May 1943 on the use of RDX in its AAF (Army Air Force) bombs, and then adopted only a less sensitive mixture with TNT known as RDX Compositon B. This first significant change in bomb-loading came about as a result of AAF insistence that the large fragmentation bombs developed in 1943 would need the greater power of RDX Composition B to burst their thick walls with the greatest effect. Henceforth, Composition B was used in only about 40 percent of the general pupose bombs. The reasons were twofold. First, the short supply caused by competition between RDX, and high octane gasoline, and synthetic rubber for production facilities and, second, the tendency of Composition B to detonate high-order without fuze action under the shock of impact. RDX was more prone than TNT to prematurely deflagrate (decompose rapidly without detonating) when employed in delayed-action bombs dropped from high altitudes. In the war-long argument over the relative merits of blast and fragmentation, the pendulum now began to swing back toward blast partly because by 1944 the AAF would have aircraft capable of delivering larger and heavier loads. After 1943, the new aluminized fillings were of far greater interest than either RDX Composition B or ednatol. Until WW II, the use of aluminum in explosives had not been extensive. Tests in 1941 in England had failed to indicate any significant difference between aluminized explosives and amatol or Composition B. In 1943, the discovery that German bombs containing aluminum were extremely effective spurred research. This led to the development of minol, a mixture of aluminum with amatol, and tritonal, a mixture of aluminum with TNT. For their 2-ton blockbuster bomb, the British favored Minol 2, a mixture of 200/o aluminum, 400/o TNT, and 400/o ammonium nitrate; and they requested that Minol 2 be used in their blockbuster bombs being loaded in the US. The British, by using new methods of blast measurement and interpretation, had learned that Minol 2 produced an area of demolition approximately 30 percent greater than the area obtained with a TNT filler. US Army Ordnance technicians had independently arrived at a similarly high opinion of the blast effect contributed by aluminum. They arrived at this conclusion by comparing the performance of oneand two-ton blockbuster bombs loaded with minol, TNT, ednatol, and the RDX mixtures. In comparing minol and tritonal, they preferred tritonal, because it contained no ammonium nitrate. When even the slightest degree of moisture was present in the air, aluminum acted on ammonium nitrate and produced "spewing" (the evolution of hydrogen gas) and explosions. Tritonal was much safer, and the British were won over to it. The AAF adopted tritonal for large, light-case bombs for jungle warfare, and for all general purpose bombs. Other bombs were filled with explosives suitable to their particular purposes. For fragmentation bombs, RDX Composition B continued to be the preferred filling because it had more brisance than tritonal. The US one-ton semi-armor-piercing bombs developed in early 1944 were loaded with picratol, a mixture of TNT and ammonium picrate, or with Explosive D. Explosive D was the least sensitive to shock and friction, which made it the best explosive to mix with TNT in a bomb that had to withstand severe shock and stress before detonating.

k. World War ll. Reverse Nitration of TNT. During 1941 and 1942 the inadequate supply of TNT for highexplosive bombs and shells was a major problem for Ordnance. Because the shortage had been foreseen, plans were made to use a substitute explosive called amatol (a mixture of TNT and ammonium nitrate) for shell or bomb loading until new TNT plants came into full production. Even so, a critical shortage of TNT developed despite these plans. But the shortage suddenly disappeared when a new process appeared on the scene almost by accident. During an inspection of a small Canadian TNT plant at Beloeil near Montreal in 1941, LTC John P. Harris of Ordnance discovered that

the plant was "doing things backward" by putting toluene into the acid instead of putting acid into the toluene. Despite some resistance by US TNT producers, the new process was tried at the partly built Keystone Plant at Meadville, PA. The result was a trippling of TNT output. Lines designed to turn out 16 tons a day produced more than 50 tons a day. The need for TNT substitutes vanished, and the cost per unit was cut in half.

l. *World War II*. Toluene from Petroleum. Development of a new means of producing toluene, the basic material from which TNT is made, was another highly significant technological advance of World War II. The importance of this chemical stems from the fact that nearly half of every unit of TNT (trinitrotoluene) must come from toluene. In World War I, toluene was derived from coal as a by-product of coke ovens, and some was extracted from natural gas. Yet the supply in 1917-18 was so limited that the Assistant Secretary of War, Benedict Crowell, later called this shortage "the greatest and most pressing of all the problems in regard to existing raw materials." In contrast, during World War II high-explosives production was never seriously hampered by lack of toluene. As early as 1927, Standard Oil of New Jersey had obtained patent rights from a German firm to use a process for producing toluene from petroleum. In 1939, a contract with Standard Oil was placed by Picatinny Arsenal to prepare toluene by this process at Baytown Ordnance Works, which was erected next to the Humble (a Standard Oil subsidiary) refinery in Baytown, TX. By October 1942 this plant was producing toluene at the rate of 246 million liters (65 million gallons) per year, which when compared with a total toluene production of less than 34 million liters (9 million gallons) in the US during 1918 shows us the value of this process.

m. *World War II*. Artillery Propellants. The problem of obtaining artillery propellants that were both flashless and smokeless continued to plague the U.S. Army. Early in the war, the Navy seized upon nitroguanidine as the one feasible answer to novel conditions of combat. For the first time, American ships in the Pacific were preparing to fight in small harbors where maneuvering was all but impossible. Flash at night betrayed the vessel's position, and smoke by day made second rounds inaccurate. Negotiations with Canada in 1943 for the purchase of nitroguanidine, from the one plant upon which British and Canadian forces were also depending, succeeded in meeting Navy needs but left no surplus for the US Army. The Army Ground Forces were not convinced of the value of this propellant until TM 9-1300-214 shortly before D-Day. By then, urgent demand could not allocate facilities to produce nitroguanidine in large quantities, and the Ordnance Department could only procure small lots for testing and experimental firing. Whatever the advantages of nitroguanidine, neither it nor any other composition was ideal for all purposes. Even in conventional artillery and small arms ammunition, where ballisticians understood propellant behavior better than in rockets and recoilless rifle ammunition, compromises were inescapable. The primary requiste for one weapon or one particular use tended to be different from every other weapon or use. In addition to these problems, World War II introduced the problem of climate extremes at which firing had to take place when Allied troops were fighting in arid deserts, damp jungle heat, or in the subzero winter weather of northern Europe and of the Aleutian Islands. Therefore, a series of propellants were needed to cover widely varying contingencies. Since basic research as well as prolonged applied research was necessary, many problems remained unsolved at the end of the war. But the field was explored more thoroughly than ever before in the United States, and lines of investigation were clarified for postwar development. In processing propellants, industry and the Ordnance Department made considerable advances during the course of the war. One new method developed by the Hercules Powder Company for washing nitrocellulose in a continuous filter instead of in large tubs by the old "settle and decant" system, washed the nitrocellulose more thoroughly and thus improved the stability of nitrocellulose. The DuPont Company found that using preheated alcohol during the winter to dehydrate nitrocellulose reduced the hydration time cycle, improved the yield, and made for a more uniform product. This in turn produced a much better powder. The Radford Ordnance Works carried on extensive experiments to improve manufacturing and testing techniques as well as for finding better chemical compositions. Yet in the spring of 1945, reports from the Combined Intelligence Objectives Subcommittee, established to locate data in Europe on Axis research and manufacturing procedures, indicated that Germany had developed several processes more effective than those of the United States. The most novel German method was one of casting propellant grains by adding a paste of moist nitrocellulose and diethyleneglycol dinitrate (DEGN) to molten TNT and pouring the mixture into steel molds to cool. Grains as large as 1,000 millimeters were cast this way. After the war, complete sets of the German equipment deemed most useful and novel went to Picatinny Arsenal for study.

n. *World War II*. Wood Pulp and Cotton Linters. Before the war, the standard practice for making smokeless powder called for the treatment of bleached cotton linters with a mixture of nitric and sulfuric acid. In the summer of 1941, it became apparent that even with a good cotton linters crop and capacity operation of bleacheries, the supply of linters for powder would fall short of requirements. Ordnance chemists, therefore, turned to the use of a special wood pulp that was available in quantity, was suitable for most kinds of powder, and was cheaper than cotton linters. The Hercules Powder Company had made smokeless powder from wood pulp for a number of years, and Ordnance found the product completely acceptable. Use of wood pulp as a supplement of, but not a replacement for, cotton linters was approved promptly except for rifle powder and certain other uses. Soon most plants had one or two lines for nitrating cotton, an equal number of lines for nitrating wood pulp, and several "swing lines", which were adaptable for use of either materials. From January 1942 to the end of the war, Ordnance plants used roughly equal quantities of cotton linters and wood pulp. There was never a concurrent shortage of both materials, although there were times when the supply of one ran low or was expected to run low. At such times, Ordnance drew upon its inventories while converting the swing lines to meet the situation. The use of wood pulp doubled the existing supply of cellulose for powder, and eliminated a serious potential bottleneck in ammunition production.

o. *World War II*. Rocket Propellants. Difficult though the US program was for improving propellants for conventional weapons, the question of developing suitable rocket propulsion was still harder to answer. From the very beginning everyone concerned with rocket research agreed that single-base powders would lack the necessary energy and that double-base powders, that is nitrocellulose and nitroglycerin combined, must be used. Double-base powders, made by the solvent process, had been manufactured in the United States for a number of years for use in intermediate and large caliber artillery. The method used a solvent of acetone and alcohol to make a colloid, from which grains or flakes could then be formed. About 1939, the Hercules Powder Company found a way of producing a solventless double-base propellant, which was plasticized by heat and pressure and then rolled out into sheets for mortar increments. But neither was adaptable for rockets where a solid stick or grain, not sheet propellant, was needed, and where the essential quality of uniform burning precluded using a grain without so much as a hair crack or fissure. Even a tiny crack in a burning grain of powder would create pressure peaks at particular spots of the encasing rocket mortar tube and thus either burst the tube or cause erratic populsion. Consequently, to get a safe usable rocket propellant made by the solvent process meant using grains of small cross-section (in technical phraseology, thinwebbed powder) in which malformations occurring in drying would be few and inspection could be exacting. A method of manufacturing solventless double-base propellant by a dry extrusion process had been developed in the late 1930's by the British. This produced much thicker-webbed, and therefore longerburning, grains, but required enormously heavy presses to extrude or compact, and force out the propellant into the desired shape.

p. *World War II* High Explosive Artillery Projectiles. Considerable power combined with sensitivity, which made for easy loading, stability, and safety in handling and transport, made TNT and amatol the preferred highexplosive fillings for most high-explosive artillery shells at the outset of World War II. This was largely due to their availability in large quantities. As the war progressed and ammunition became more complex in design and more specialized in function, demand arose for improved explosives. This demand could not be met to any extent because the explosives developed between wars did not get into large-scale production in time. Nevertheless, thoughout the war the US Army Ordnance Department sought ways of using more powerful new explosives, and ways to adapt old ones to special purposes. There were at hand several explosives of higher shattering effect, or brisance, than TNT. The most important were, first, cyclotrimethylene trinitramine, which the Americans called cyclonite and the British called RDX ("Research Department Explosive"); second, pentaerythritol tetranitrate or PETN; and third, EDNA (later called haleite). RDX and PETN were too sensitive to be used in the pure state in a shell. Therefore, to form usable compositions it was necessary to combine them with oils or waxes or with other explosives. The British had managed to desensitize RDX by adding nine percent beeswax to form Composition A for press-loading into shells; with 39.5 percent TNT and one percent beeswax to form Composition B, chiefly for bomb loading; and with 11.7 percent of a plasticizing oil to form Composition C, for demolition work. These formulas were provided by the British to the US in 1940, and development work was undertaken by the DuPont Company under contract of the Ordnance Department.

The most sensitive of all high explosives was PETN, which was even more readily detonated than RDX. PETN was desensitized by mixing with TNT to form a composition named pentolite, which has been extensively used in detonators, bazooka rockets, rifle grenades, boosting devices, and in the shaped charges of antitank shells. Because of production difficulties, haleite, the most promising of the new high explosives, never saw much use in World War II except in the form of ednatol in mixtures with other explosives.

q. World War II Armor-Piercing and Antitank Projectiles. Much of the work of improving high-explosive compositions was directed toward finding the most efficient filling for anti-tank shells. For armor-piercing projectiles, relatively insensitive ammonium picrate, "Explosive D," had long been preferred. As it was not likely to detonate on impact, the shell could penetrate the armor plate before exploding. But experience with heavy German tanks in North Africa showed that something more was needed in the way of power and fragment action coupled with greater incendiary effect within the tank. Chemists at Picatinny Arsenal accordingly tried several expedients. In armor-piercing shell, addition of a small amount of powdered aluminum to cyclotol (a mixture of RDX and TNT), to ednatol, or to TNT produced more brisance than Explosive D and increased sensitivity to impact. In high-explosive antitank shell fillings, conversely, the difficulty was the exact opposite. The high sensitivity of pentolite made it liable to detonation on target impact so that the problem was to desensitize it to the proper degree. Several possibilities considered were the addition of wax to the pentolite, the reduction of the PETN content, and the substitution of ednatol or Composition B. None was entirely satisfactory. The search for an explosive composition of the greatest possible power and brisance took a new turn after analysis of foreign explosives at Picatinny Arsenal during 1943. Hitherto, research had been concentrated on binary explosive compositions such as pentolite, Composition B, or ednatol. The examination of a Soviet 76mm high-explosive armorpiercing round suggested the possibility of employing ternary mixtures. Tests revealed that castable ternary explosive mixtures, such as RDX-Tetryl-TNT and Haleite-PETN-RDX, offered promise not only for armor-piercing projectiles but as fragmentation ammunition for weapons designed to produce blast, and for demolition charges. Further study showed that haleite ternaries were unstable. The best combination seemed to be a mixture of PETN-RDX-TNT designated PTX-2 (Picatinny Ternary Explosive). More brisant than any of TM 9-1300-214 the binary compositions, PTX-2 was more stable than 50/50 pentolite and less sensitive to impact. Preliminary firings at Picatinny indicated that PTX-2 would be particularly adaptable to shaped-charged ammunition; but PTX-2 was still in the testing stage at V-J Day.

r. World War II. Shaped Charges. If no new explosive for artillery shell came into use during the war, a new way of employing explosives nevertheless did. The effect of a hollow-charge or shaped-charge projectile against armored targets was first successfully demonstrated by the bazooka and the rifle grenade. The intense forward jet of the charge, serving to focus part of the energy of the explosion in a limited area, gave to the light-weight, low-velocity rocket the armor-piercing advantages hitherto possessed only by high-velocity artillery. The antitank rifle grenade, containing only 113 grams (4 oz) of pentolite, would penetrate up to 102mm (4 inches) of homogeneous armor plate at a normal angle of impact. The first rifle grenade to use this principle was designed by a Swiss inventor, Henri Mohaupt, whose claims of inventing a "new explosive" had interested the British in 1939. However, the price Mohaupt quoted for his discovery was considered too high and the British showed no further interest in his invention. Mohaupt then offered to show the United States particulars of the construction of his device for a fee of $25,000 paid in advance. Caution on the American part further delayed acquiring the rights until a demonstration by Mohaupt at Aberdeen Proving Ground, MD, was permitted in 1940, doubtlessly because Mohaupt provided 200 grenades for the demonstration. Army and Navy representatives who witnessed the test firings were convinced that this was indeed an important "new form of weapon." A similar proposal by Nevil M. Hopkins, an American inventor, for a shaped-charge bomb had been rejected earlier by the United States Ordnance Department as not being a new concept. By citing a 1911 British patent by Egon Neuman of the "Munroe-Neuman" principle, the Ordnance Patent Section thereupon showed Mohaupt's "secret" to be no secret. Thus the Ordnance was able to conclude a more reasonable contract with Mohaupt's company than the Swiss had originally demanded. An adaption of Mohaupt's design later formed the basis for the M9A1 antitank rifle grenade, and the 2.6-inch antitank "bazooka" rocket. Application of the shaped-charge principle to artillery naturally proceeded. The choice of howitzers was logical because their low velocity made conventional types of armor-piercing projectiles ineffective, whereas for a shaped-charge explosive low velocity was an advantage. Before Pearl Harbor, in an

atmosphere of great secrecy, work began on a shaped-charge shell, specifically the "HEAT" (highexplosive antitank) round, for the 76mm howitzer. The designers, paying careful attention to the length of the ogive, the filler of 50/50 pentolite, and the striking velocity, came up with a round of the same length as the corresponding high-explosive round. The HEAT round, at a muzzle velocity of approximately 305 meters per second, would penetrate 76 millimeters (3 inches) of homogenous armor plate. A similar shell for the 105 millimeter howitzer appeared simultaneously. Standarized in late 1941, HEAT shells were produced in time to take part in the North African tank battles early in 1943. The Ordnance Department had high hopes that the HEAT rounds would succeed in penetrating the heavy German armor plate that had defeated solid armor-piercing ammunition. Although sometimes successful, the performance of shaped charges was not dependable enough. In an effort to find out why, the Ordnance Department, with the help of the National Defense Research Committee (NDRC) and the Navy, intensified its research. In some cases, observers in the field had blamed faulty manufacture, but investigators proceeded on the assumption that design of the round and the principle of operation needed improvement. Because of the difference in behavior of the nonrotating rocket and the rotated shell, the effect of the spin was carefully studied as well as the method of fuzing. One of the most important discoveries was that an increase in plate penetration was directly proportional to an increase, up to approximately three calibers, in "standoff" distance, that is, the distance from the base of the cone to the target at the moment of detonation. Yet this finding was only a beginning, and the solution to the puzzling behavior of hollow charge projectilles was not found during World War II.

s. *World War II Smoke Screening Munitions*. In the spring of 1940, the Germans demonstrated the value of smoke to screen their advance when they blitzed the Low Countries. Basic developments in smoke employment during World War II were its use to screen river crossings, beach landings, paratrooper assaults, and rear area targets from artillery fire and aircraft observation and attacks. Prewar versions of the HC smoke pots were enlarged, and floating smoke pots were developed for amphibious operations. Aircraft smoke tanks were developed for spraying liquid smoke mixtures. Smoke generators were developed for screening large areas by vaporizing fog oil. White phosphorous (WP) was the choice filler for most projectiles, but also had the undesirable disadvantage of sometimes becoming an incendiary. Another disadvantage was that WP tended to melt in hot climates, which affected the stability of the round in flight. Storage in hot climates also resulted in expansion of the WP and subsequent leakage. Despite these shortcomings, WP was very effective for building up smoke screens as particularly demonstrated by the 4.2-inch mortar battalions in Europe and the Pacific. Smoke bombs filled with WP and PWP were used extensively for spotting targets and for screening parachute drops. Plasticized WP or PWP was developed to reduce the pillaring effect of the exploding munition found with pure WP. PWP is obtained by mixing WP with a very viscous solution of synthetic rubber to form a homogenous mass. For loading into munitions where a longer lasting smoke screen is desired, HC (hexachloroethane mixture) was preferred, e.g., smoke pots and base ejection shells. WP was used in rifle grenades. HC was used in hand grenades. US tanks in North Africa were outfitted with smoke grenade launchers to screen the tanks from antitank fire.

t. *World War II*. Pyrotechnics for Illumination. In 1944, the Army Air Forces (AAF) made an important change in doctrine that affected munition development requirements when they initiated 24-hour bombing operations. Night bombing, always favored by the Royal Air Force but hitherto opposed by the United States, gave new importance to pyrotechnics. Aircraft flares came close to the usual bomb design. The AN-M26 aircraft parachute flare, designed to provide illumination for night bombardment, contained its illuminant mixture in a round-nosed, finned-tail cylinder and developed 800,000 candlepower for about three minutes. The most important development concerned high-altitude night photography, and markers to identify targets at night. The prewar M46 photoflash bomb gave only 500 million candlepower. Picatinny Arsenal experimented with different combinations of case, filler, and initiating system. The result was a photoflash bomb that produced approximately three times as much light as the M46. Target identification bombs grew out of a technique evolved by the British to improve the accuracy of their night bombing. Their "Pathfinder Force" equipped with special navigational aids flew over a target in advance of the attacking force and dropped various kinds of candies and flares, some to illuminate the general area and others to mark the special target with color. One munition designed specifically for

this work was a stabilized bomb that ejected sixty-one pyrotechnic candles at a predetermined altitude. In the United States, the earliest research on target identification markers produced five bombs of this type. All were modifications of the 250-lb general purpose bomb and differed one from the other in the type of candle they contained. The candles were small flares that burned with either red, green, or yellow light for about three minutes. Each target identification bomb released its load of these signal candles, which together made a pattern of colored light approximately 100 meters in diameter around or on the target. These signal candles were designed to be visible from altitudes as high as 35,000 feet. To keep the candles from being disturbed while they were on the ground, one type of candle had an explosive charge that would detonate at the end of the burning time of the candle, the time being from one to two minutes. As the AAF extended its night operations, especially low-level bombing and strafing of illuminated targets by fighters and light attack bombers, need arose for ground burning flares that would produce a minimum amount of smoke and thus leave the targets as clear as possible. For this purpose, the Ordnance Department developed flare bombs loaded with smokeless units. At the end of the war Army and Navy experts agreed that future developments must be aimed at greatly increasing the candlepower, burning time, and visibility of all pyotechnics, especially the photoflash bomb.

u. *World War II*. Pyrotechnics for Signaling. With the use of massive bombing air raids and close ground support by the Army Air Forces came the need for better signaling devices. Especially important were hand signals for downed fliers. Survival kits were developed which included colored smoke and flare distress signals for the aviators to carry. A substantial improvement in the ground signals used by the Armed Forces was made when the US Army Chemical Warfare Service (CWS), now the Chemical Corps, made a change in the method of consolidating the colored smoke mixtures in the grenades used for this purpose. The prewar M1 colored smoke grenades used a slow-burning mixture that burned about two minutes. In 1942, the Army Ground Forces established a requirement for a colored smoke grenade that would form a smoke visible at a slant range of 3,050 meters (10,000 feet) and last about one minute. By devising a method of consolidating the pyrotechnic smoke mixture with heavy presses, CWS engineers were able to provide a grenade meeting the Army TM 9-1300-214 Ground Forces' requirements. After limited testing, the new grenade was type classified as the M18 smoke grenade and was issued in four colors: green, red, violet, and yellow. The M18 grenade remains the most widely used signaling device for ground troops today, which is a remarkable achievement considering that the M18 was adopted for Army use within six weeks of the statement of the requirement. This same loading technique was later applied to artillery base ejection canisters for marking boundaries.

v. *World War II*. Flame and Incendiary Munitions. In the intervening years from World War I to World War II, the development of flame weapons was studied by most nations except the United States. During the Ethiopian War in 1935 and 1936, the Italians employed the first armored vehicle-mounted flamethrowers. The Germans employed a flame tank during the Spanish Civil War and in 1939 used portable flamethrowers in Poland. These instances proved to the United States that the development of flame weapons could no longer be denied. In 1940, the US Army took steps toward developing a flamethrower and a flamethrower tank. These flamethrowers served an important role in the war in the Pacific, particularly in dislodging the determined Japanese soldiers from caves and fortifications. On Okinawa alone, flamethrowers are credited with the capture or death of 20,000 Japanese soldiers who were holed up in the caves while less than 100 American flamethrower operators were killed in the operations. The development of napalm ("nap" for the napthenic acids and "palm" for the coconut fatty acids which made up the first type of this thickner) by the United States in 1941 made possible the greater use of gasoline for use in flame weapons. This gelled mixture made it possible for aircraft to deliver fire bombs over hard-to-get pinpointed areas and for flamethrowers to project a flame rod over a greater distance than was previously obtainable. By August 1944 the United States AAF Board had come to the conclusion that "where there is vulnerability to fire, the damage by fire is greater than by demolition," a conclusion, to be sure, that observers had reached during the London blitz of 1940 but which had not been acted upon. The decision of the Board in 1944 was to increase the incendiary bomb program to the highest priority. The United States Army CWS provided the Army Air Force with about 48 million incendiary bombs, which were effectively used, especially on the large cities of Japan. Most of these bombs were clustered bomblets containing thermate (TH3 and TH4), a new

incendiary mixture, which replaced the original thermite mixture. When ignited, thermate burns intensely at 2,2000C. Molten iron from burning thermate will melt metal, burn through steel plate, and ignite flammable materials. Oil and metal incendiary mixtures, such as PT1 and PTV, were also used as fillings in large thincased bombs. PT1 is a complex mixture based on "goop," a paste comprised of magnesium dust, magnesium oxide, and carbon, with a sufficient amount of petroleum distillate and asphalt to form the paste. PTV is an improved oil and metal incendiary mixture of polybutadiene, gasoline, magnesium, sodium nitrate, and p-aminophenol. However, napalm proved to be one of the most effective aerial incendiary agents in the war. On the evening of 9 March 1945, more than 300 superforts (B29 bombers) swarmed over Tokyo dropping about 2,000 tons of incendiaries, mostly clusters of M69 six-pound bomblets. The M69 bomblet was a tube which contained a black powder propellant charge that ignited and projected the napalm filling from the tube. Aerial photos indicated 16 square miles had been burned out. Tokyo police records, examined after the war, showed that more than 250,000 buildings were destroyed about one fourth of Tokyo in this one raid. More than 100,000 tons of incendiaries were dropped on the cities of Japan during World War II. Most of these were M69 bomb clusters. For destroying materiel to prevent enemy use, the CWS developed a thermate grenade, which was standardized as the AN-M14 TH3 incendiary grenade for use by the Army and Navy. Harvard University also developed a napalm fire starter (MI), for use by troops to ignite fires in wet climates. The armament of the American heavy bombers was usually the .50 caliber machine gun. During World War II, enemy fighter aircraft did not have armor plating capable of deflecting a .50 caliber bullet, although, bullet penetration of the plane's armor did not necessarily knock out aircraft. The enemies use of self-sealing fuel tanks necessitated the development of effective incendiary ammunition. Most urgently needed was an effective .50 caliber incendiary round. The first acceptable design was the work of the Remington Arms Company whose staff already had considerable experience in working on Swiss patents for incendiary ammunition. The Remington development was based upon the British .303 B Mark VI Z, and was adopted in September 1941. The bullet was a flatbase type with lead base closure and steel body, and was charged with 35 grains of a incendiary mixture consisting of 50 magnesium alloy and 50 percent barium nitrate. An improved design was developed shortly thereafter by Frankford Arsenal and was standardized for United States use.

2-9. Post-World War II Developments. The nuclear bombs that ended World War II did not end requirements for conventional explosives and ammunition. As was shown by the Korean War (1950-1953) and the Vietnam War (1964-1973), the need for the United States to develop even more effective munitions and more powerful explosives or energetic materials became more apparent than ever. In spite of intensive effort, chemists at the Army's laboratories and arsenals failed during World War II to develop a new explosive composition for shell loading that was both satisfactory and readily available in quantity. The obstacles were often disheartening. The characteristics of an explosive might be considerably affected by impurities that existed in the raw material or which were admitted during manufacture. For example, the instability of PETN was probably due to impurities in the raw material, pentaerythritol. Other variables that had to be taken into account were the different methods of testing compositions and the differences in interpreting results. Assuming a composition had been found that promised to combine greater brisance with less sensitivity, there was still the question of whether it could be economically manufactured, safely handled, and made unchanging in character in temperatures ranging from arctic cold to tropical heat. In the search for explosives with special properties, much work had been done in the field of aluminized explosives, but, although aluminized TNT (tritonal) was used in bombs, much remained to be done. At the end of the war the Ordnance Department felt that deeper study of the fundamental properties of all high explosives was essential to effective developments in the future. Some of the problems of finding suitable high explosives and propellants have been resolved in the decades following World War II. Other problems have cropped up as the expanding techniques of modern warfare lead to more and more specialized requirements for explosives and propellants. Future developments may be expected to take the direction chiefly of mixtures of currently known explosives and other materials. But in some cases, the requirements can be satisfied only by new and more powerful explosives which are presently being sought. As seen by the experience of the two world wars, scientists engaged in the field of energetic materials must keep abreast of foreign technology and be prepared to exploit technical intelligence. The everchanging and rapid advance of

technology makes it necessary to shorten the lead time from research and development to deployment of new ammunition and explosives. But research and development is only the tip of the iceberg; the biggest expenditures for materiel in the Army go to the procurement and management of ammunition. An Army cannot fight for long without the right kinds of ammunition being available in the necessary mix and quantities needed to perform its mission. A responsive, flexible, viable production base and balanced inventories must be maintained to assure a strong readiness posture. With continuing budget restraints, all those in the armaments research and development community must consider these restrictions and exercise close control of the limited resources allocated to them for this purpose. Therefore, scientists and technicians working in this field must direct their priorities for research and development to those projects with the best prospects of being beneficial to armed forces materiel readiness, and avoid projects that may have only marginal applications to wars of the future.

a. *1945*. PLX (Picatinny Liquid Explosive), consisting of 95 percent nitromethane and five percent ethylenedinitramine, was developed at Picatinny Arsenal by L. H. Eriksen and J. W. Rowan for use in mine clearing. The Germans had used similar liquid explosives during World War II under the name Myrol.

b. *1945*. Tripentaerythritol octanitrate was patented by J. A. Wyler of Trojan Powder Company, PA, for use as a high explosive and possible gelatinizer for nitrocellulose.

c. *1946-1949*. Composition C-4, known as Harrisite, was developed by K. G. Ottoson at Picatinny Arsenal as a replacement for Composition C1, C-2, and C-3. Composition C-1, C-2, and C-3 were the United States standard plastic RDX demolition explosives, and were originally derived from Britian's Composition C, which was developed during World War II.

d. *1946-1949*. Benite, a black powder substitute, was developed at Picatinny Arsenal for use in igniter compositions of artillery primers, or in base igniter bags for separate-loading ammunition. Benite is in the form of extruded strands consisting of ingredients of black powder in a matrix of nitrocellulose.

e. *1946-1949*. Composition D-2, which is not an explosive but serves as an emulsifier and desensitizer of explosives like HBX-1, was developed. Composition D-2 consists of 84 percent wax, two percent lecithin, and 14 percent nitrocellulose.

f. *1950-1953*. When World War II ended, the United States had a tremendous inventory of ammunition on hand, but unfortunately it was not a balanced stock. There were enormous quantities of some types of ammunition, and only small amounts of others. The hasty mobilization of manpower for the Korean conflict stripped the Ordnance Department of the military and civilian personnel that might have properly assessed and cared for the huge inventories of ammunition in its custody. During the years preceding the Korean War, powder packed in cotton bags and fuzes made of substitute metals deteriorated. The Army drew too freely upon the large ammunition stockpile for training purposes, yet made no real effort to replace consumption or balance the items in stock. The lack of postwar orders sent the ammunition industry into an eclipse. When the United States entered the Korean struggle so suddenly in 1950, ammunition facilities and plants were at a low ebb, and businessmen were reluctant to reconvert their factories to wartime effort. Another element that restrained a shift to the immediate production of ammunition was the prevalent belief that the Korean War would be short, and did not warrant a sizeable dislocation of the United States industrial effort. Even after this fallacy was shattered by the entry of the Chinese into the war in late 1950, the policy of butter and guns continued, and no large scale mobilization of industry took place. Compounding the situation of unbalanced stocks, the lack of industrial mobilization that normally follows the outbreak of war led to further setbacks in the battle for ammunition production. By the time funds budgeted in 1951 were translated to production in 1953, the war was practically over. In the meantime, the answer to the shortages in Korea was for the Army to reduce the authorized ammunition required supply rates in the belief that the combat units were wasting their ammunition. The net result was a war in which American firepower could not be used to its best advantage. The lesson learned from this is that a need for better industrial mobilization planning, and for closer contact with industry in the development and maintenance of a viable production base exists.

g. *1950-1973*. During the Korean conflict, both portable and mechanized flamethrowers were used and found to be very effective. Flame mines, using incendiary bursters to set off 55-gallon drums of napalm, were used in a defensive role. The large batches of napalm required for these operations were mixed in truckmounted service units. M1 fuel thickening compound was used to gel the gasoline for flamethrowers and landmines. An undesirable feature of M1 thickener is that it absorbed moisture rapidly from the air, which degraded the gelling properties so that the gel became unstable. Army chemists at Edgewood Arsenal, MD, began work on a nonhygroscopic thickener, which was standardized later as M4 flame fuel thickening compound. The M4 flame fuel thickening compound is a di-acid aluminum soap of isooctanoic acids derived from isooctyl alcohol or isooctyl aldehyde, which are obtained from the oxidization of petroleum. Because of the large World War II surplus inventory of M1 thickener, M4 thickener was not produced in quantity until the Vietnam War. The Air Force used tremendous quantities of fire bombs. These bombs were essentially large fuel tanks filled with napalm, which were ignited by pyrophoric igniters (WP or sodium) upon impact. Continuous process mechanical mixers were developed for use at Air Force bases to mix and fill the fire bombs on the spot. M1 thickener could be mixed only in batches, so a new thickener, M2, was developed and fielded. M2 flame fuel thickening compound is an intimate mixture of 95 percent M1 thickener and five percent devolatilized silica aerogel or other approved antiagglomerant. M2 thickener was an improvement of the M1 thickener for use in fire bombs. This is because of the free-flowing and fast-setting characteristics, which allow its use in continuous mechanical mixers. M2 thickener was not suitable for use in flamethrowers, which require an aged gel obtained in the batch process. Napalm B, a special fire bomb fuel formulation, was developed by the Air Force to replace M2 thickener. Napalm B currently consists of 46 percent polystyrene, 21 percent benzene, and 33 percent gasoline by weight. Napalm B withstands high velocity impact dissemination more effectively than M2 thickened gasoline gels, resulting in less fuel burned enroute and more fuel delivered on target.

h. *1950*. MOX (metal oxidizer explosives) were developed by National Northern Technical Division of the National Fireworks Ordnance Corporation, West Hanover, Mass, for use mostly in small caliber antiaircraft shells.

i. 1952. Military medium velocity dynamite was developed by W. R. Baldwin, Jr. at Hercules Powder Company Laboratory.

j. 1952. PB-RDX (plastic-bonded RDX) was developed by the Los Alamos Scientific Laboratory of the University of California for use as a mechanical strength explosive. PB-RDX consisted of 90 percent RDX, 8.5 percent polystyrene, and 1.5 percent dioctylphthalate.

k. 1957. Military low velocity dynamite was developed at Picatinny Arsenal by H. W. Voigt.

l. 1958. HTA-3 (high temperature explosive) consisting of 49 percent RDX, 29 percent TNT, and 22 percent aluminum was prepared at Picatinny Arsenal.

m. 1958. Octols 70/30 and 75/25, mixtures of HMX and TNT, were developed at Northern Corporation as fillers for bombs and shells. Octols are standard high explosive fillers, which have been adopted for Army use.

n. 1958. Slurry explosives were developed by M. A. Cook and H. E. Farnham by adding water to ammonium nitrate to form slurries of the oxidizer salt, ammonium nitrate and sodium nitrate, and a solid fuel sensitizer. Slurry explosives provide three to six times the detonation force of ammonium nitrate-fuel oil (ANFO) explosives.

o. 1960. Detaclad process or explosive cladding, which is also called explosive bonding, was developed by the DuPont Company.

p. 1960. Detacord, detaflex flexible cord explosive, and detasheet flexible sheet explosives were developed by the DuPont Company.

q. *1964-1973*. The war in Southeast Asia (SEA) (Vietnam) was characterized by an imbalance of ammunition supplies to meet the peculiar requirements of a longer, different type of war than had been anticipated. In the beginning, much of the war had to be fought with the ammunition surpluses from World War II and Korea. Critical shortages developed on those ammunition items which were best suited for the type of war being fought. Ammunition supply rates had to be adjusted constantly because production problems at home delayed filling vital requirements. The expanded use of the helicopter in this war and the fielding of rapid firing armament, such as the "Gatling" 40mm automatic cannon raised the supply rates far beyond the planners' expectations. The demand for signaling devices, such as the M18 colored smoke grenades, doubled, tripled,

and continued to rise until the ammunition supply rates for the grenades were as much as 100 times the World War II and Korea rates. Due to ammunition shortages, terrain, climate, and guerrilla warfare, the United States troops were often forced to rely upon field expedients during their missions. A new development program called ENSURE (Expedited Non-Standard Urgent Requirement), whose function was to meet troop demands for special items needed to support SEA operations, was established by the Defense Department. Many of the ENSURE items fielded under this program were ammunition related and are now standard items for Army use. For example, although flamethrowers were used extensively in SEA, a stand-off capability to project flame was needed to reduce the vulnerability of the operator to enemy fire. From this ENSURE requirement, a 66mm multishot flame rocket launcher (M202 and M202A1) was developed. The resulting M74 incendiary TPA incendiary 66mm rocket was fielded and is now a standard item. The rocket is filled with TPA (thickened pyrophoric agent), which consists of triethyl aluminum (TEA) thickened with polyisobutylene (PIB). Other significant ENSURE developments were a broad range of various 40mm cartridges and signaling devices, improved mines, and pyrotechnics for battlefield illumination.

r. *1973*. The problem of managing a rapidly increasing number of conventional ammunition items in the Army inventory was addressed at the conclusion of the war in Vietnam. Although.many items developed as a result of the ENSURE program had justified their existence in combat, others were, by their very nature "field expedients" or were advance prototypes from ongoing development programs' In addition, many of the items in the inventory were obsolescent left over from Korea, World War II, and even pre-World War II assets. Accordingly, the Deputy Chief of Staff for Logistics (DCSLOG), Department of the Army, established an Ammunition Proliferation Study Committee staffed with representatives from the developing arsenals (Picatinny, Frankford, and Edgewood), the National Inventory Control Point, and the United States Army Training and Doctrine Command (TRADOC). This committee, chaired by DCSLOG, was assigned to review every conventional ammunition item with a stock number or every ammunition item in development, and recommend deletion of all items considered not essential to the mission of the Army. Hundreds of obsolescent and non-essential items of ammunition and explosives were eliminated. Among these were FS smoke and M1 thickener. Ammunition supply rates were considered. For example, because of a low usage factor, the AN-M14 TH3 incendiary grenade was considered for elimination until it was established that the incendiary grenade was used only when necessary to destroy equipment to prevent enemy use; therefore, ammunition supply rates are not applicable to this item. Retention of the M18 violet smoke grenade was justified because violet was the second most used color for signaling in Vietnam; and more colors, not less, were needed to prevent the enemy from guessing the purpose of the signal.

s. *1973-1976*. To protect tanks, the United States Army devoted considerable attention to the problem of rapidly screening tanks from enemy antitank rounds and missiles. A DARCOM Project Manager for Smokes and Obscurants was appointed to manage a program of developing and fielding countermeasures. One of the first items adopted for Army use was a British smoke grenade launcher, which fires salvos of red phosphorous (RP) UK L8A1 smoke screening grenades from armored vehicles. After launch, these grenades detonate in the air to form an immediate, dense white smoke cloud that obscures the tank from enemy view. Smoke grenade launchers have been developed for use in many of the armored vehicles in use or development today, including the M1 tank.

CHAPTER 3
GENERAL CHARACTERISTICS AND CLASSIFICATION OF ENERGETIC MATERIALS

3-1. Types of Energetic Materials. Energetic materials are chemical compounds, or mixtures of chemical compounds, that are divided into three classes according to use: explosives, propellants, and pyrotechnics. Explosives and propellants that have been properly initiated evolve large volumes of hot gas in a short time. The difference between explosives and propellants is the rate at which the reaction proceeds. In explosives, a fast reaction produces a very high pressure shock in the surrounding medium. This shock is capable of shattering objects. In propellants, a slower reaction produces lower pressure over a longer period of time. This lower, sustained pressure is used to propel objects. Pyrotechnics evolve large amounts of heat but much less gas than propellants or explosives.

3-2. Characteristics of Burning and Detonation. Burning and detonation of energetic materials are exothermic redox reactions. The reaction is selfsustaining after an initial activating energy has been applied. On the basis of mass, the amount of energy released by propellants and explosives is comparable. However, this energy is considerably less than is produced by common fuels such as carbon burning in air. Propellant burning, or deflagration, is the very rapid burning that results from having a fuel and an oxidant in very close contact. In some propellants such as nitrocellulose, the fuel (which consists mainly of hydrogen and carbon) and oxygen are parts of the same chemical compound. In other propellants, finely divided discreet fuels and oxidents are mixed. The fuel may be a hydrocarbon or other readily oxidizable material such as aluminum. The oxidizer is usually an inorganic compound such as ammonium perchlorate or ammonium nitrate which contain oxygen in excess of the amount required for their own oxidation. Deflagration of propellants proceeds the same as normal burning. Combustion takes place on the surface and proceeds into the grain. The rate determining factors in the reaction are the rate of heat transfer into the propellant grain from the burning surface and the rate of decomposition of the propellant formulation. The rate of heat transfer depends on the pressure of the combustion products. The burning rate is defined as the rate at which the burning surface consumes a propellant grain in a direction normal to the grain surface. Detonation of explosives is a completely different process than deflagration. A shock wave moving at supersonic speed proceeds through the explosive causing decomposition of the explosive material. The reaction rate is determined by the velocity of the shock wave, not by the rate of heat transfer. The velocity of the shock wave depends on the physical characteristics of the individual explosive material. The range of velocities is from about 2,000 meters per second to about 9,000 meters per second. The factors that affect the velocity include density, degree of confinement, and geometric configuration of the charge.

3-3. General Behavior of Pyrotechnic Compositions. Pyrotechnics is the technology of utilizing exothermic chemical reactions that, generally speaking, are non-explosive, relatively slow, self-sustaining, and self-contained. Pyrotechnic compositions are generally finely divided fuels such as metals, alloys, and hydrocarbons mixed with oxidizers.

3-4. Classification of Energetic Materials. There is considerable variation among the properties of the compounds that constitute each of the three major classifications of energetic materials.

a. The variation in the properties of explosives is put to practical use in armaments by an arrangement called an explosive train (figure 3-1). An explosive train consists of elements arranged according to decreasing sensitivity and increasing potency. The first element, the initiator, consists of a small quantity of highly sensitive material. The highly sensitive material consists of a primary explosive and other ingredients. Primary explosives are easily detonated by heat, spark, impact, or friction. In large quantities these materials are extremely hazardous because of their great sensitivity. The other ingredients in the priming composition increase the sensitivity of the mixture to the desired property, such as percussion or heat. The second element, the booster, contains a larger quantity of less sensitive but more powerful material called a secondary or high explosive.

The booster is used either as an intermediate stage to detonate material that is too insensitive to be detonated by the relatively weak initiator or to ensure complete detonation of the main charge. The main or bursting

charge, also a secondary explosive, is the least sensitive material but comprises the bulk of the explosive charge. Secondary explosives differ from primary explosives in three major ways. Small, unconfined charges (one to two grams) of secondary explosives, even though ignited, do not transfer easily from a burning or deflagration reaction to a detonation. Except in the case of dust clouds, ignition by electrostatic spark is difficult. The shock required for ignition is much greater for a secondary explosive than for a primary explosive. In some cases, two other elements, a delay and a relay, may be added to the explosive train between the initiator and booster. The delay is calibrated to prevent detonation of the booster for a specified length of time. A delay is considered a pyrotechnic device. A relay may be required to strengthen the relatively weak output of the delay to detonate the booster.

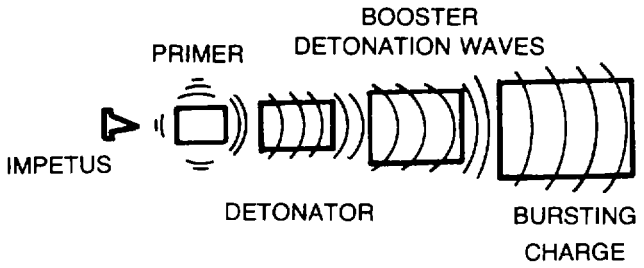


Figure 3-1. Explosive train.

b. An ignition train, which is used to ignite propellant charges, is shown in figure 3-2. The primer contains a priming composition which consists of a mixture of fuels and oxidants that are sensitive to stimuli such as impact, heat, or spark. Application of the appropriate stimulus causes ignition. The primer ignites the igniter which in turn ignites the propellant charge. The igniter is considered a pyrotechnic device.

c. Propellants are divided into four classes: single-base, double-base, triple-base, and composite. Division of the propellants into these classes is on the basis of composition, not use. Single-base compositions are used in cannons, small arms, and grenades; double-base compositions are used in cannons, small arms, mortars, rockets, and jet propulsion units; and triple-base compositions are used in cannon units. Composite compositions are used primarily in rocket assemblies and jet propulsion units. The choice of a propellant for a specific use is determined by ballistic and physical requirements rather than on the basis of composition. A given propellant composition may be suitable for use in several applications.

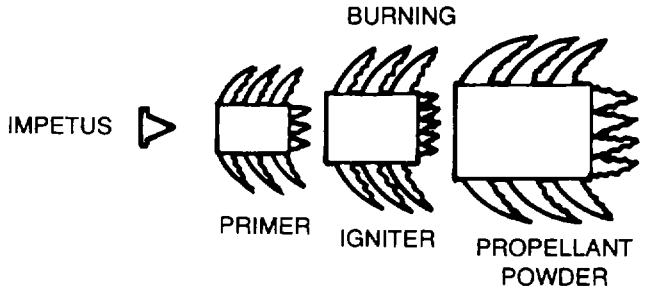


Figure 3-2. Ignition train.

(1) Single-base. These compositions contain nitrocellulose as their chief ingredient. In addition to a stabilizer, they may contain inorganic nitrates, nitrocompounds, and nonexplosive materials, such as metallic salts, metals, carbohydrates, and dyes.

(2) Double-base. This term has been applied generally to compositions containing both nitrocellulose and nitroglycerin. However, since other gelatinizers such as DEGN are used by other countries, a better definition of a double-base composition is one containing nitrocellulose and a liquid organic nitrate which will gelatinize nitrocellulose. Like single-base propellants, double-base propellants frequently contain additives in addition to a stabilizer.

(3) Triple-base. This term is applied to propellants containing three explosive ingredients with nitroguanidine as the major ingredient. The other two explosive ingredients are usually nitroglycerine and nitro-cellulose. As in the double-base propellant, other gelatinizers may be substituted for the nitroglycerine. The nitroguanidine in the formulation produces a lower flame temperature and a greater amount of gaseous combustion products. The lower flame temperature considerably reduces erosion of gun barrels and the greater amounts of gas produce a greater force on the projectile. Triple-base propellants also contain additives in addition to a stabilizer.

(4) Mixed nitrate esters. Two propellant compositions were developed in the United States to replace the triple-base formulation due to the shortage of nitro-guanidine. The XM35 composition contains nitrocellulose, TMETN, TEGDN and DEGDN. The higher force XM34 formulation contains nitrocellulose, BTTN, TMETN and TEGDN. The combination of mixed nitrate esters give higher gas volumes and lower flame temperatures than nitroglycerin alone.

(5) Composite. Most composite propellants contain neither nitrocellulose nor an organic nitrate. They generally consist of a physical mixture of a fuel such as metallic aluminum, a binder which is normally an organic polymer (generally a synthetic rubber which is also a fuel), and an inorganic oxidizing agent such as ammonium perchlorate. These are heterogeneous physical structures.

d. Pyrotechnic compositions are divided into the following categories according to use.

(1) Flares and signals. Flares burn to produce intense light that is used for illumination. Signals produce colored flames that are used as semaphores.

(2) Colored and white smoke. Colored smoke is used for signaling while white smoke is used for screening.

(3) Tracers and fumers. Tracers and fumers are small, smoke producing charges that are placed in projectiles. During the flight of the projectile, the charge burns. In a tracer, the smoke is used to track the flight of the projectile. A fumer produces smoke at the proper rate to fill the partial vacuum that movement through the air creates behind the projectile. This cuts drag and increases range.

(4) Incendiaries. Incendiaries produce large amounts of heat that cause fires.

(5) Delays and fuses. A delay is an element that consists of an initiator, a delay column, and an output charge or relay in a specially designed inert housing. The delay column burns for a predetermined amount of time. Delays are used to provide an interval between initiation and functioning of a device. A fuse is a cord of combustible material commonly used in demolition.

(6) Photoflash composition. Photoflash powders are loose mixtures of oxidizers with metallic fuels. When ignited, these mixtures burn with explosive violence in a very short time. The mixtures are used to provide light for military aerial photography, and in simulator devices.

(7) Igniters and initiators. These devices are used to ignite propellant charges and initiate detonation in explosive charges.

3-5. Chemical Nature of Energetic Materials.
Chemical properties of individual energetic materials are discussed in the appropriate chapters of this manual. The properties discussed for these materials include the following:

a. Heat of Fusion. The heat of fusion is the amount of heat necessary to transform (melt or fuse) a unit of solid into a liquid at the same temperature and standard pressure. This quantity is usually expressed in terms of calories per gram.

b. Heat of Vaporization. The heat of vaporization is the amount of heat necessary to convert a unit of liquid to vapor at the same temperature. This quantity is usually expressed in terms of calories per gram.

c. Heat of Sublimation. The heat of sublimation is the amount of heat necessary to convert a weight of solid directly into vapor in a constant temperature process. This quantity is usually expressed in calories per gram.

d. Heat of Detonation. Two quantities are usually given for the heat of detonation, one with liquid water in the reaction products and one with gaseous water in the reaction products. The test used to determine these quantities uses a standard calorimeter. When the water is allowed to condense to liquid, the total heat produced by the detonation reaction is measured. The heat of detonation with gaseous water more accurately reflects the process of detonation in a non-laboratory setting. However, the results are less reproducible.

e. Heat of Combustion. The heat of combustion is the amount of heat produced when a material is burned. This differs from the heat of detonation because the products formed are different. Generally, the products formed in combustion are at a lower energy level than the products formed during detonation. For example, carbon monoxide and carbon dioxide may be products of both detonation and combustion for a particular explosive. However, the detonation process might produce more carbon monoxide, while combustion might produce more carbon dioxide.

f. Sensitivity. Various external stimuli can cause release of the energy contained in energetic materials. Knowing the response of individual energetic materials to specific stimuli is important from the point of view of safety and in determining the suitability of a material for a specific application.

(1) The response to a blow is called impact sensitivity. Traditionally, explosives have been subjected to falling weights to measure impact sensitivity. The results are then reported as the distance a given weight must fall to produce detonation 50 percent of the time. The physical significance of this type of test has recently been questioned. The results are more qualitative than quantitative. For example, there is no question that lead azide is much more impact sensitive than TNT and that TNT is much safer to handle than lead azide. But the quantitative meaning of "much more impact sensitive" is ill-defined. The results of this test should be considered for general comparisons among explosive compounds. These same remarks are also valid for sensitivity to friction. Tests which are more applicable to specific hazards and applications such as the SUSAN test and 40-foot drop test are discussed in Chapter 5.

(2) Sensitivity of an explosive to shock is a very reproducible quantity. Shocks generated by a donor explosive can cause detonation in another explosive material. The strength of the shock wave required is a relative measure of the sensitivity of the material under test. In practice, a strong shock is produced and attenuated in an inert medium. The width of the medium that will allow detonation in 50 percent of the trials is reported as the test result. These tests are called gap tests. Gap test results are much more reliable data than impact test results, although there is some dependence on the geometry of the test apparatus. Gap test procedures are covered in detail in Chapter 5.

(3) Electrostatic sensitivity is an important quantity because of safety. Some explosives can be detonated from the shock of a person charged with static electricity. The test procedure used to determine electrostatic sensitivity is covered in Chapter 5.

(4) Thermal sensitivity is an important quantity which needs to be determined in considering explosives for applications. In some cases, such as in the warhead of a high speed intercepting missile, the heat generated during flight can cause detonation of explosive charges that are not highly resistant to heat.

g. *Brisance*. Brisance is the shattering capability of an explosive. Several tests are commonly used to determine brisance. In the sand test 0.400 grams of the explosive are placed in 200 grams of sand and detonated. The amount of sand crushed by the explosive is a measure of brisance. The plate dent test, in which a sample of the explosive is detonated in close proximity to a metal plate, is also used to measure brisance. The size of the dent is proportional to the brisance. Another method of measurement involves detonating a sample of explosive on top of a cylinder made of copper and measuring the contraction in length of the cylinder. The number, size distribution, and velocity of fragments produced by an explosive in a projectile is also related to the brisance of the explosive.

h. *Detonation Velocity*. The detonation velocity is simply the rate at which the detonation reaction proceeds through an explosive. This quantity is closely related to the brisance. With a limited number of exceptions, increased detonation velocity increases brisance.

i. *Power*. The power of an explosive is the total energy available to do work. This is a different quantity than brisance, even though on the surface they appear rather similar. Consider two explosives, ammonium nitrate and RDX. If a charge of each is placed beneath a boulder, the ammonium nitrate might hurl the boulder many meters but the RDX might pulverize the boulder into many fragments. The former quality is power whereas the latter quality is brisance. Power is measured by the Trauzl lead block test in which a sample of the explosive is detonated in a cavity in a lead block. The expansion of the cavity is a measure of the power of the explosive. The ballistic pendulum and ballistic mortar tests are also used to measure power. A heavy weight is accelerated by the detonation of an explosive. The swing of the pendulum or movement of the mortar's weight is a measure of the power of the explosive. The oxygen balance of the explosive is closely related to the power. The oxygen balance is the ratio of oxygen contained in the explosive material to the amount of oxygen required for complete oxidation of the explosive material. Explosive compositions with better oxygen balances are more powerful.

j. *Stability*. Stability is the ability of energetic materials to retain, unaltered, such properties as detonation velocity and sensitivity after long periods of storage under adverse conditions. All energetic materials are unstable to some extent. The degree of instability varies greatly. TNT can be stored for 20 years with no change in stability while other explosives, which are not used by the military or commercially, decompose and/or detonate in a matter of days or minutes. Several tests are used to measure stability of explosives. In the heat tests, a sample of the explosive is subjected to a specified temperature for a given amount of time. The

sample is then weighed and any loss of weight above the evaporation of moisture indicates volatility or decomposition. The heat tests are usually carried out at 75°C or 100°C. In the 75±C test a ten gram sample is heated for 48 hours then cooled and weighed. In the 100°C heat test two samples of the explosive weighing 0.60 grams each are heated to 100°C. One of the samples is withdrawn after 48 hours, cooled, weighed, and replaced in the oven. This sample is then withdrawn after an additional 48 hours of heating, cooled and weighed again. The second sample is left in the oven for 100 hours and any detonation or ignition is reported. The 100°C heat test is a more accurate predictor of stability than the 75° test. The currently preferred test of this type, however, is Thermal Gravimetric Analysis (TGA). A TGA can be run in two ways. The temperature can be held constant and the weight is monitored continuously. The data is then plotted as weight or percentage of weight change versus time. The other method commonly employed is to vary the temperature at a specified rate and plot the weight or percentage of weight change versus temperature. The results reported in this manual use a sample size of approximately 10 milligrams and a heating rate of 10°C per minute. The vacuum stability test is used extensively to measure stability. In this test a sample of an explosive is subjected to both elevated temperatures and vacuum. The amount of gas evolved after a specified time is recorded as the test result. The test may be run at any temperature but between 100°C and 150°C is the most common temperature range. In Chapter 5 the test procedure is given in detail. A test that is sometimes performed is the KI (potassium iodide) test. In this test a strip of potassium iodide starch test paper is suspended in a test tube with the material under test. The top of the strip is saturated with a 50 percent water 50 percent glycerin solution. The sample is heated. As the heating continues, moisture condenses on the test tube up to a certain point. The position of the test paper is moved up so the line of demarcation between the dry and glycerin-water soaked portions is kept level with the ring of condensation. The appearance of discoloration of the upper half of the test paper indicates the test is finished. The results are reported as the amount of time from the start of heating to the end of the test. A blank is run at the same time to ensure the test results are greater than the time required for the blank to indicate. This test is of limited applicability. The discoloration is caused by acidity, so the major application is testing nitrocellulose at 65.5°C and nitroglycerin at 82.2°C for purity. A test that is performed on explosives to determine stability is the LLNL reactivity test. In this test a sample of explosive is heated at 120°C for 22 hours. A two stage chromatography unit is used to measure the individual volumes of N_2, NO, CO, NO_2, and CO_2. The result is the sum of the volumes of these gasses per 0.25 gram of sample. A test that yields a great deal of useful information is the Differential Thermal Analysis (DTA). Detailed testing procedures for explosives are given in Chapter 5. In the usual DTA analysis, identical containers are set up. The sample under test is placed in one of the containers and a reference substance is placed in the other. The containers are placed in identical thermal geometries with temperature sensors arranged to give both the temperature of each container and the difference in temperatures between containers. The data are displayed as DTA thermograms; the temperature difference is plotted against the temperature of the sample. The standard reference material chosen is one with thermal behavior that does not change rapidly. Such a plot is nearly a straight line if the sample under test also has no rapidly changing thermal behavior. A straight line is also produced if the test sample has thermal characteristics similar to the reference substance. Excursions above and below a background line result from endothermic or exothermic changes. The DTA analyses permit interpretation for phase changes, decomposition and kinetic information, melting points, and thermal stability. Another very useful test is pyrolysis. A sample is placed in a pyrolysis chamber that is then flushed with helium. When the air has been swept out, the temperature of the chamber is raised at a constant rate. Gas evolution is measured as a function of temperature by a bridge formed by two thermal conductivity cells. The pyrolysis test results are plotted with the DTA results for each explosive.

CHAPTER 4
CHEMISTRY AND PHYSICS OF ENERGETIC MATERIALS

4-1. Introduction. This chapter contains a discussion of the physical processes involved in the detonation and deflagration of energetic materials. The initiation phenomenon, blast effects in surrounding media, and shaped charge principles are also discussed.

4-2. The Ignition-Initiation Process. Direct ignition or initiation of explosives by an external stimulus is caused by the thermal decomposition of the explosive involved. Impact, friction, electrostatic discharge, gap, and other sensitivity tests produce hot spots in the material under test. A hot spot is a localized region of higher than average temperature. Existence of the hot spots is confirmed by the lag time between the application of the stimulus and the detonation or ignition. For example, if a two kilogram weight falls 30 centimeters on a 20 milligram sample of RDX, ignition occurs within several hundred microseconds. Assuming that the impact energy heated the sample uniformly and that no heat loss occurred, the temperature of the RDX would be about 250°C. At that temperature, the ignition lag for RDX is about one second. In solid explosives, energy is transferred out of the hot spot in the form of shock and rarefication waves. The shock wave heats the surrounding explosive. Some hot spots fail to detonate the surrounding material. Whether or not an explosion occurs depends upon the initial strength of the shock wave and how rapidly the shock decreases at the hot spot interface. Several modes of hot spot generation which have been proposed include:

a. Adiabatic heating due to compression of gas spaces can operate in impact and friction initiation of pressed solid and liquid explosives.

b. Frictional heating on a confining surface or on a grit particle can cause a hot spot. This mode of initiation can operate in impact and friction initiation of pressed solid and liquid explosives.

c. Hot spots can be caused by the intercrystalline friction of the energetic material. This mode of initiation can operate in impact and friction initiation of pressed solid explosives.

d. Viscous heating at high rates of shear can create hot spots. This mode of initiation is operative only at strong shock inputs. This is the main mode of initiation and propagation in homogeneous liquid explosives or defect-free single crystals.

e. Heating by plastic deformation at a sharp point can cause hot spots. This mode is operative in the shock initiation of solid explosive compacts and explosive liquids containing inhomogeneities.

f. Hot spots can be formed by the mutual reinforcement of relatively weak shock waves at inhomogeneities in the shocked medium. This mode is operative in the shock initiation of solid explosive compacts and explosive liquids containing inhomogeneities.

g. Particles which are spalled off crystallite by an incoming shock wave can form hot spots by impact on the opposite wall of a void. This mode is operative in the shock initiation of solid explosive components or liquid explosives containing inhomogeneities.

h. Micro shaped charged jets which are formed by shock waves acting on concave walls of bubbles, cavities, or voids can cause hot spots. This mode is operative in the shock initiation of solid explosive compacts or liquid explosives containing inhomogeneities.

4-3. The Deflagratlon Process. Deflagration of a propellant proceeds in a direction normal to the surface of the propellant grain. Material is consumed in parallel layers, so the geometry of the grain does not change as the burning takes place. Propellant is volatized by heat transfer from the flame zone which is in the gas phase above the propellant surface. An increase in the ambient pressure causes the flame zone to move closer to the propellant surface. This increases the rate of heat transfer. The more rapid heat transfer causes an increase in the rate of volatilization of the propellant which correspondingly increases the rate of deflagration. If the flow pattern of the hot combustion gases is perturbed and penetrates the flame zone, an increase in the rate of heat transfer may occur. An increase in the flame temperature also causes an increase in the rate of heat transfer. The flame temperature is a function of the propellant composition. Propellants tend to burn more smoothly at high pressure than at low pressure.

4-4. Deflagration to Detonation Transfer (DDT). In some energetic materials deflagration can build to detonation. In a DDT, local ignition forms a convective flame front. A convective flame front is an ignition wave which is propagated by the passage of hot combustion gases through the pores of the charge. The hot gases are forced into the pores of the charge by the pressure built up as a result of charge confinement. The hot gases heat the pore walls and are consequently cooled. A continuous flow of gases is required to raise the temperature of the pore walls to the point of ignition. Ignition of the pores causes the convective flame front to advance and as the convective flame front advances, the pressure increases linearly with time. The pressure increase causes compaction of most porous charges. Formation of a post convective or compressive wave marks the beginning of accelerated pressure buildup. Subsequent coalescence of the compressive waves into a shock wave completes the DDT. The degree of compaction of the explosive determines how much material is consumed before the DDT occurs. The runup distance is defined as the length of material which will deflagrate before detonation occurs. The following subparagraphs describe the physical phenomenon involved in the variation of runup distance with density of the explosive material.

a. At crystal density and in cast charges there is no porosity and the explosive is impermeable. A convective flame front cannot form. A DDT can occur only if the explosive is relatively sensitive and there is a rapid pressure rise in the ignition region that produces a sufficiently strong shock wave. Some high explosives when unconfined at this density will burn without detonation. Under sufficient confinement, however, these explosives will detonate. Other more sensitive explosives will explode even without confinement.

b. The introduction of porosity into a charge does not mean that the charge will be permeable since the pores may or may not be interconnected. If the pores are not connected, permeability is very low and essentially negligible. The criteria for DDT in this case will be the same as for cast charges. The runup distance will be smaller, however, because the porosity will increase the exposed surface area of the explosive. This will cause 4-2 the rate of change of the pressure with respect to time to be slightly higher than for the cast material. If an explosive does not undergo DDT at crystal density, then there would probably not be a DDT at this density.

c. As the porosity increases, the fraction of pores which are interconnected increases rapidly. However, the permeability of the charge should remain small. Under these conditions a convective flame front can be established. Establishment of the front will depend on the permeability of the charge, the adiabatic flame temperature of the explosive, ignition characteristics of the explosive, and the ability of the confinement to allow a critical driving pressure to be established. The onset of convective burning indicates that nonnegligible amounts of energy can be transported by gas flow beyond the ignition region. However, only very small quantities of gas can flow out of the ignition area over a time period as long as 100 microseconds. The runup distance for DDT in this case would be less than for charges with either lesser or greater porosity.

d. As more porosity is introduced into the charge, the gas flow can no longer be described as choked. Enough pores are connected to permit flow which may be described as steady state. The increased permeability for this case leads to smaller rates of pressure increase near the ignition point. Burning for a longer period of time is required before the rate of pressure increase begins to accelerate. DDT occurs only after the acceleration occurs. A sharp rate of pressure increase is required to produce compressive waves which can coalesce into shock waves. The runup distance is correspondingly increased.

e. For very permeable charges, the runup distance increases with increasing porosity. Energy losses from the burning region can be great enough to prevent a rapid enough rate of pressure rise to cause DDT. In this case, the pressure builds relatively slowly (in one to two hundred microseconds) to a high level. The high pressure crushes the porous material immediately around the ignition region. The greater density crushed material, upon combustion, may then produce a rapid enough pressure rise to cause DDT. The runup distance for this case is the longest of any of the cases discussed.

4-5. The Detonation Process.

a. Detonation is caused by a self-sustaining shock wave which passes through an explosive material. The velocity of the shock wave is also called the velocity of detonation. A shock wave is a very rapid, almost discontinuous change in pressure. Beyond the range of the pressures involved in transmission of sound through a medium, the propagation velocity of a pressure wave increases as the pressure increases. Shock waves are formed by a pressure pulse of sufficient amplitude. The high pressure region of the pressure pulse moves faster than the low pressure region and so catches up as shown in figure 4-1. The shock wave will continue to have the sharp pressure rise shown in figure 4-1c until the wave is dampered out. The dimension of the x-axis can be either distance or time. Five variables relate the state of the region in front of the shock wave and the region behind the shock wave. The variables are illustrated in figure 4-2. The shock velocity is the velocity at which the shock wave moves through the material. The shock velocity is greater than the sound velocity of the material at a given density. The particle velocity is the velocity attained by the material as a result of the acceleration of the shock wave. Particle velocity is in the same direction as shock velocity. Pressure, density, internal energy, and temperature increase as a result of the passage of the shock wave.

b. To derive relationships between the variables that specify shocked and unshocked material, refer to figure 4-3. We assume the shock front is stationary and the material is moving at the shock velocity through the shock front. Application of the laws of conservation of mass, momentum, and energy yields the following relationships among the variables.

(1) In a given amount of time, t, mass moves from one side of the shock front to the other side. By definition, mass, m, is given as a function of density, p, and volume, V, by the equation:

$$m = pV \qquad (4\text{-}1)$$

The volume, V, can be expressed in terms of area, A, and length, L, by the equation:

$$V = AL \qquad (4\text{-}2)$$

The length, L, is the distance a particle travels in our assumed time interval, t, times the velocity, v:

$$L = tv \qquad (4\text{-}3)$$

By figure 4-3 the velocity can be seen to equal:

$$v_0 = (v - u_0) \qquad (4\text{-}4)$$

and

$$v_1 = (v - u_1) \qquad (4\text{-}5)$$

By equations 4-1 through 4-5 the mass entering the shock front is:

$$m_0 = p_0 v_0$$
$$m_0 = p_0 AL$$
$$m_0 = p_0 At(v - u_0)$$

Similarly, the mass leaving the shock front is:

$$m_1 = p_1 v_1$$
$$m_1 = p_1 AL_1$$
$$m_1 = p_1 At(v - u_1)$$

Invoking the principle of conservation of mass:

$$m_0 = m_1$$
$$p_0 At(v - u_0) = p_1 At(v - u_1)$$
$$p_0(v - u_0) = p_1(v - u_1) \qquad (4\text{-}6)$$

(2) In our system the force produced is the pressure difference across the shock acting on the cross-sectional area:

$$F = (P_1 - P_0)A$$

The rate of increase in momentum of the system is the final momentum less the initial momentum per unit time or:

$$\text{momentum change}/t = (mu_1 - mu_0)/t$$

By equations 4-1 through 4-5:

$$\text{momentum change}/t = \left[p_1 Atu_1(v - u_1) - p_0 Atu_0(v - u_0)\right]/t$$

Setting the force equal to the rate of momentum increase per unit time:

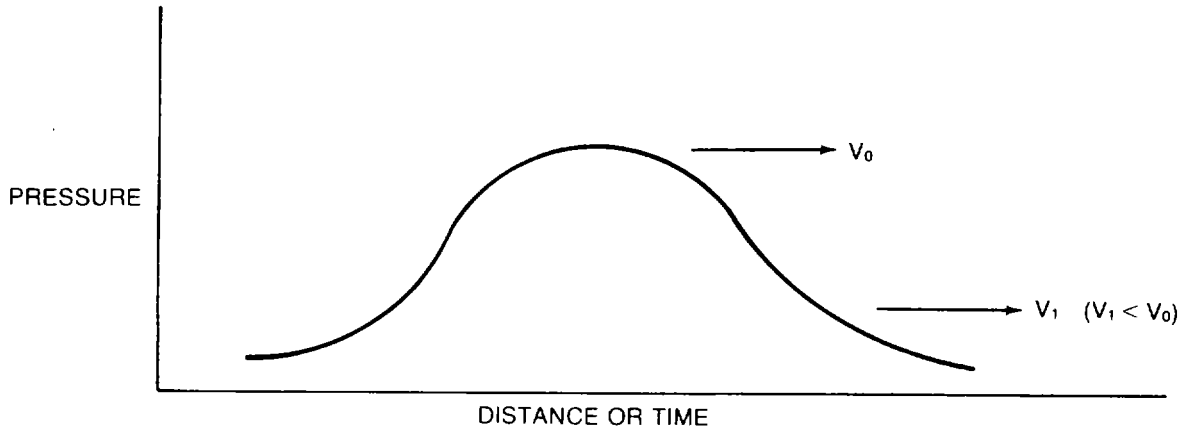
$$(P_1 - P_0)A = \left[p_1 Atu_1(v - u_1) - p_0 Atu_0(v - u_0)\right]/t$$

Cancelling and rearranging yields:

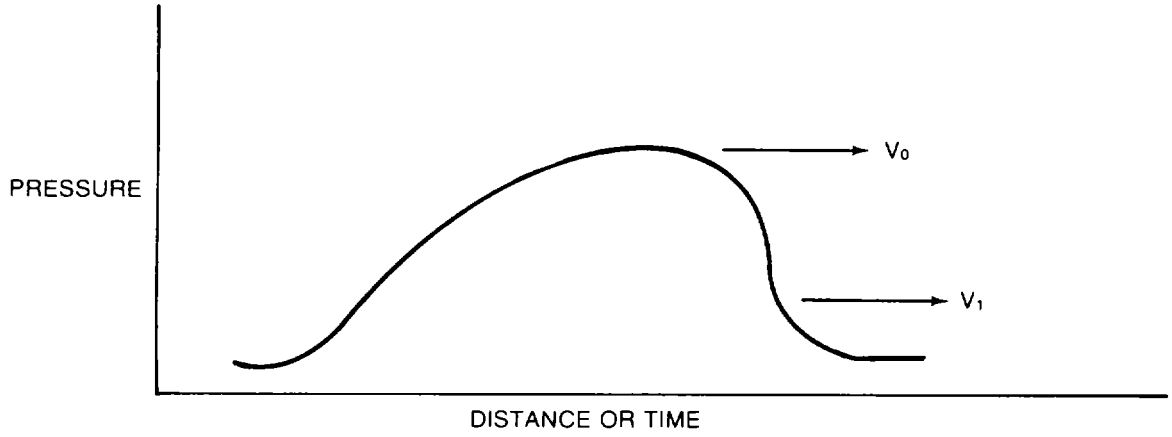
$$P_1 - p_1 u_1(v - u_1) = P_0 - p_0 u_0(v - u_0) \qquad (4\text{-}7)$$

(3) The rate of work being done on the system, w, per unit time, t, is given by the equation:

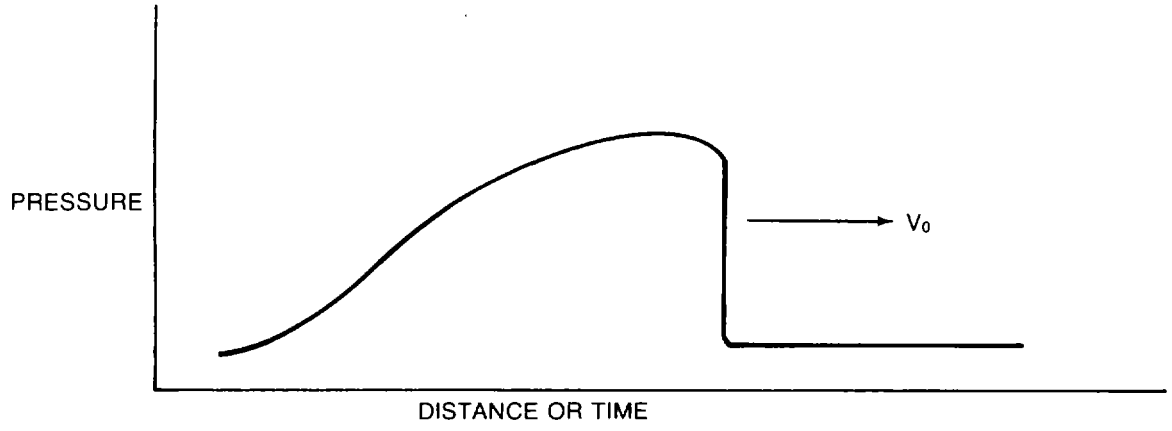
$$w/t = p_1 Au_1 - p_1 Au_0$$



A. A PRESSURE PULSE



B. DIFFERENTIAL VELOCITY CAUSES THE LEADING EDGE TO BECOME SHARPER



C. A SHOCK WAVE

Figure 4-1. Shock wave formation.

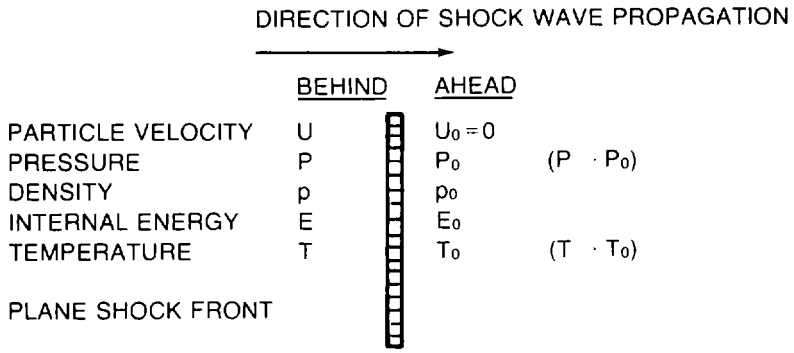


Figure 4-2. Steady plane shock front.

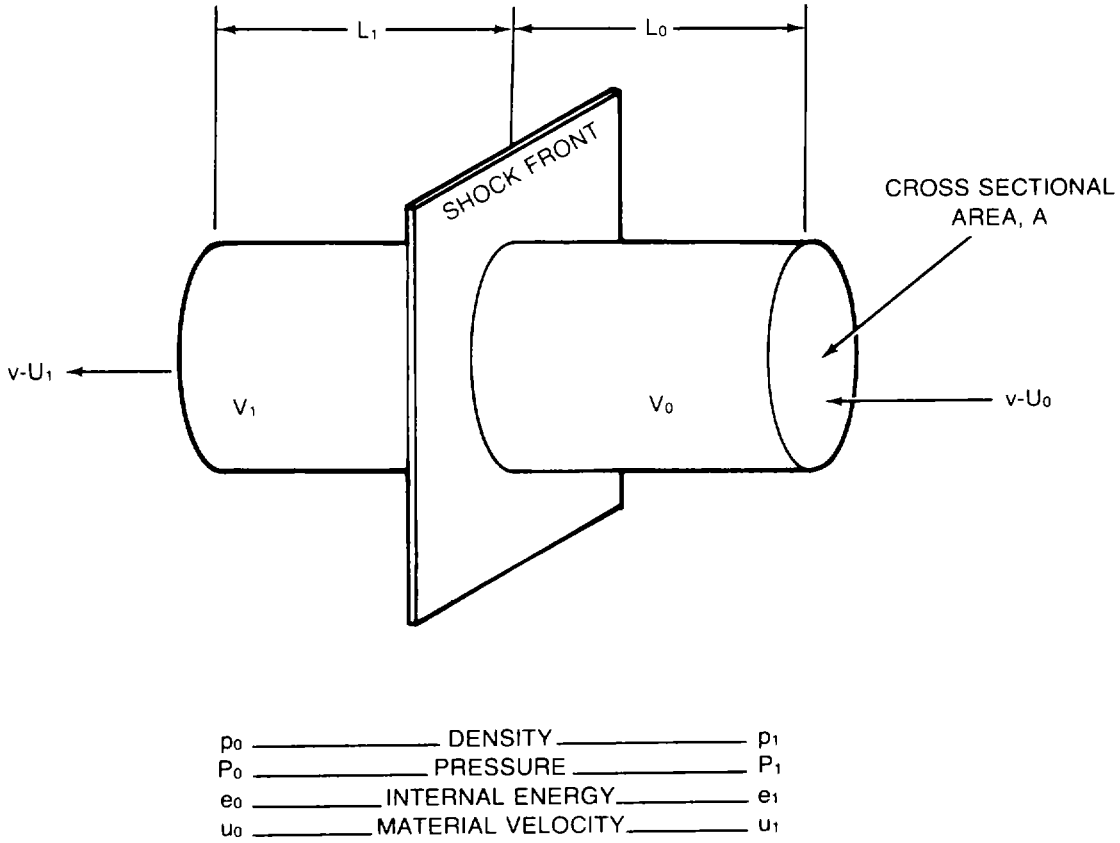


Figure 4-3. Control volume or mass passing through a shock front.

The rate of increase of energy per unit time is the difference between the rate of change of the sum of the internal and kinetic energies in the initial and final state:

increase energy /t =

$$[(p_1AL_1e_1 + 0.5p_1AL_1u_1^2) - (p_0AL_0e_0 + 0.5p_0AL_0u_0^2)] /t$$

Using equations 4-1 through 4-5 the increased energy can be expressed as:

$$[(Atp_1 (e_1 + 0.5u_1^2) (v-u_1) - Atp_0 (e_0 + 0.5u_0^2) (V - u_0^2)] /t$$

Equating the work done on the system with the rate of energy increase and canceling the *t's*:

$$p_1u_1A - p_0u_0A =$$
$$Ap_1 (v - u_1) (e_1 + 0.5u_1^2) - Ap_0 (v - u_0) (e_0 + 0.5u_0^2)$$

Canceling the A's yields:

$$p_1u_1 - p_0u_0 =$$
$$p_1 (v - u_1) (e_1 + 0.5u_1^2) - p_0 (v - u_0) (e_0 + 0.5u_0^2)$$

Rearranging terms yields:

$$p_1u_1 - p_1 (v - u_1) (e_1 + 0.5u_1^2) =$$
$$p_0u_0 - p_0 (v - u_0) (e_0 + 0.5u_0^2) \quad (4\text{-}8)$$

(4) Equations -6, 4-7, and 4-8 are called jump equations because the state variables jump from one value to another very rapidly across the shock. To these, another relationship tying together any of two state variables (*P, v, u, e, t, p)* which is specific for a given material is needed. An equation of state, which completely describes the material is more than is needed. A simpler relationship called the Hugoniot equation suffices. The Hugoniot is determined experimentally. The relationship can be obtained by measuring shock pressure and velocities at various shock states, or shock velocity and particle velocity, or any two of the state variables simultaneously. The Hugoniot which describes the relationship between the shock velocity, *v*, and particle velocity, *u*, has been found to be:

$$v = c_o + su \quad (4\text{-}9)$$

where c_o is the sound velocity in the medium and *s* is a constant that is related to the specific heat and thermal expansivity of the material. This relationship is not a path along which the variables change, but is actually a locus of solutions or discreet shock states. Table 4-1 lists the values of c_o and *s* for several explosives in the unreacted state.

Table 4-1. Unreacted Hugoniot Data

Explosive	Density in grams per cubic centimeter	Temperature °C	cc in millimeters per microsecond	*s*	Range of *u* (by experiment) in millimeters per microsecond
Ammonium nitrate	0.86	25	0.84	1.42	0.81 - 2.32
Composition B	1.70	25	3.0 ± 0.04	1.73	0.0 - 1.5
Composition B	1.68	25	2.71 ± 0.05	1.86 ± 0.07	0.0 - 0.9
DATB	1.78	25	2.45 ± 0.04	1.89 ± 0.06	0.0 - 1.2
H-6	1.76	25	2.83 ± 0.07	1.70 ± 0.08	0.0 - 1.1
H-6	1.76	25	2.65	1.98	0.0 - 2.0
HBX-1	1.75	25	2.93 ± 0.08	1.65 ± 0.10	0.0 - 1.0
HBX-3	1.85	25	3.13 ± 0.02	1.61 ± 0.02	0.0 - 1.0
HNS	1.38	25	0.61 ± 0.21	2.77 ± 1.09	0.0 - 0.5
HNS	1.57	25	1.00 ± 0.05	3.21 ± 0.10	0.0 - 0.7
75/25 Octol	1.80	25	3.01 +0.4	1.72	0.0 - 1.2

Table 4-1. Unreacted Hugoniot Data - Continued

Explosive	Density in grams per cubic centimeter	Temperature °C	cc in millimeters per microsecond	*s*	Range of *u* (by experiment) in millimeters per microsecond
50/50 Pentolite	1.67	25	2.83 ± 0.4	1.91	0.0 - 1.2
PETN	0.82	25	0.47	1.73	0.76 - 3.50
PETN	1.0	25	0.76	0.66	0.28 - 0.42
PETN	1.59	25	1.33 ± 0.08	2.18 ± 0.27	0.03 - 0.37
PETN	1.60	25	1.32	2.58	0.2 - 0.4
PETN	1.72	25	1.83	3.45	0.2 - 0.6
PETN	1.55	110	-0.6 ± 0.5	8.7 ± 1.7	0.24 - 0.29
RDX	1.0	25	0.40	2.00	0.44 - 2.60
RDX	1.54	25	0.7	3.2	0.25 - 0.6
RDX	1.58	180	0.71 ± 0.24	4.22 ± 0.42	0.25 - 0.32
RDX	1.64	25	0.70 ± 0.18	4.11 ± 0.37	0.35 - 0.47
RDX	1.80	25	2.87	1.61	0.75- 1.6
RDX	1.64	25	1.93 ± 0.05	0.666 +0.168	0.11 - 0.35
TATB	1.85	25	2.34 ± 0.07	2.32 ± 0.08	0.3 - 1.4
TNT	1.62	25	2.93	1.61	0.75- 1.6
TNT	1.63	25	2.57	1.88	0.0- 1.25
TNT	1.62	25	2.27 ± 0.30	2.65	0.0 - 0.6
TNT	1.62	25	2.99	1.36	1.0- 1.5
TNT	1.61	25	2.39 ± 0.03	2.05 ± 0.03	0.0 - 1.4
TNT	1.64	25	2.08 ± 0.13	2.3	0.2 - 1.4
TNT	1.64	25	2.4	2.1	0.1 - 0.5
TNT (liq)	1.47	92	2.14	1.57	0.8 - 1.7

By substituting terms from equations 4-6, 4-7, and 4-8 into equation 4-9 and solving, we can obtain more forms of the Hugoniot, for example:

$$P = p_0(c_0u + su^2) \qquad (4\text{-}10)$$

(5) Three planes or two dimensional plots are used to describe the shock properties and shock histories of materials. They are the distance-time (x-t) plane, the pressure-particle velocity plane (P-u) described by equation 4-10, and the pressure-specific volume (P-vs) curve.

(a) The -t plane is used to display the positions of shocks, material surfaces, and rarefications (the opposite of a shock) in time and distance.

Figure 4-4 shows a simple collision of two materials. (1) is the surface of the target and (2) is the front surface of a flyer plate which is a small mass that impacts the target at a very high velocity. The slope of (2) is the plate velocity, (3) is the impact point when the two materials meet, (4) is the forward going shock in the target, (5) is the interface of the plate and target moving slowly to the right, (6) is the left going shock driven back into the flyer, and (7) is the back surface of the flyer. All slopes on this plot are velocities. As the shocks reflect and rarefications fan out and the surfaces move, the x-t plot is used to keep track of the variables.

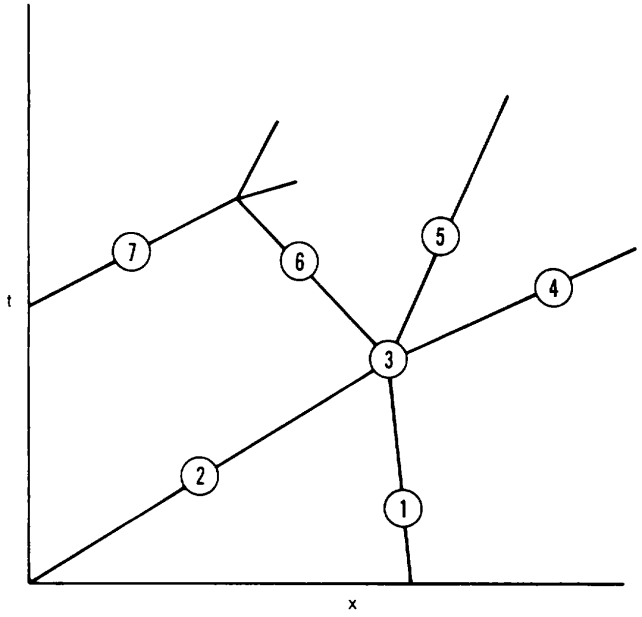


Figure 4-4. Shock properties in the x-t plane.

(b) The P-u plane is where the Hugoniots are normally plotted. An example is shown in figure 4-5. This plot is used to perform graphical solutions to impact problems (uniaxial). Intersections of Hugoniots represent simultaneous solutions of two Hugoniot equations. Chords drawn from initial to final states on this plot have slopes proportional to the shock velocities of the final state in that particular material. Figure 4-5 shows the solution of an impact problem where a flyer, material N at a velocity of u_0 impacts a stationary target, material M. The final pressure and particle velocity after the impact are the same in both flyer and target and are $P_1$and u_1 respectively. (1) is the chord drawn from the initial state to the final state of the flyer. The slope is equal to P_0vt, the initial density times the shock velocity in the flyer. (2) is the chord drawn from the initial state to the final state of the target, the slope of the chord is P_0vr, the initial density of the target times the shock velocity in the target. The negative slope of P_0vf indicates the shock in the flyer is traveling toward the left. The lines N and M are the P-u Hugoniots of two individual materials. The P-u Hugoniot is not fixed on the plane. The position of the plot relative to the P and u axis is not unique. The physical explanation for that is, a material specimen can exist at any pressure state regardless of bulk or particle velocity. The shape of the Hugoniot and the relation of slope to the axis is unique.

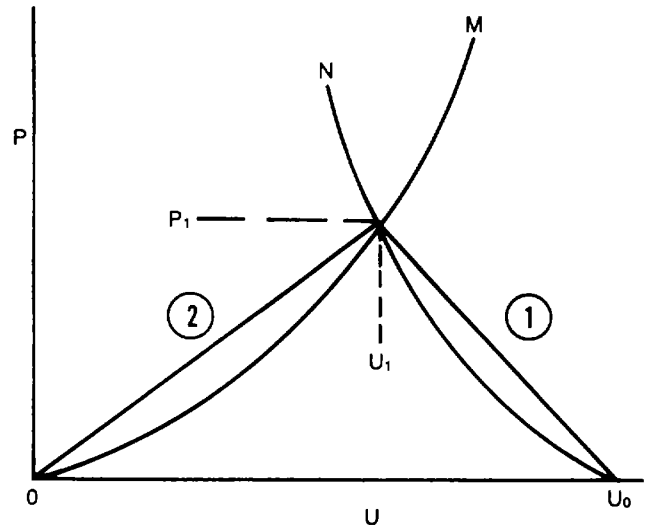


Figure 4-5. Shock properties in the P-u plane.

(c) The specific volume Vs is defined as the reciprocal of the density. Plots in the P-Vs plane, as shown in figure 4-6, are useful in describing the thermodynamics of the shock because areas on this plane represent work or energy per unit mass:

$$PVs = \frac{Force}{Area} \quad \frac{Volume}{Mass} \quad \frac{Force\ X\ distance}{mass}$$

The Hugoniot position on this plane is unique.

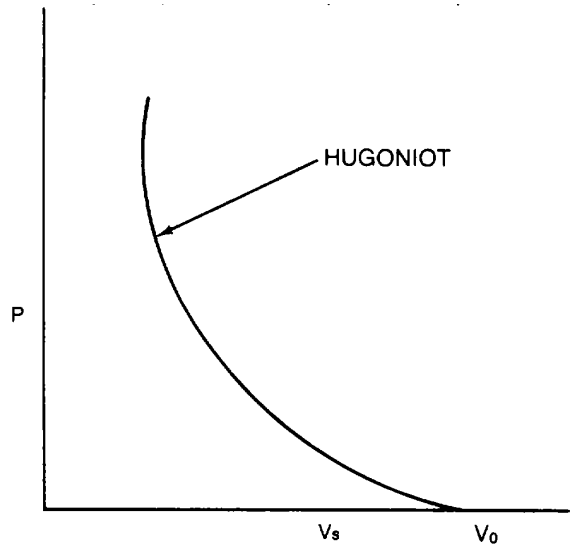


Figure 4-6. Shock properties in the P-Vs plane.

c. A detonation shock wave is self-sustaining because the energy added by the chemical reaction taking place behind the wave balances the losses due to normal attenuation. Figure 4-7 shows the pressure distribution of a detonation wave that is moving through explosive material. Chapman and Jouquet (CJ) developed the theory of shock wave propagation through explosive materials. The CJ conditions for each explosive are unique for that explosive at some unique or specified density. If we change the initial density, we will change the CJ conditions. The theory is based on these assumptions: that pressure is constant from the shock wave to the CJ point, that the pressure decays in a Taylor wave beyond the CJ point, that the reaction is complete and the products are in equilibrium at the CJ point, and that the energy in the Von Neuman spike is negligible in comparison to the energy in the reaction zone and so can be ignored. Figure 4-8 shows a representative plot of the Hugoniots of unreacted explosive and decomposition products under detonation conditions. The Rayleigh line connects the initial unshocked state, V_{s0}, with the final shocked state, VF. Table 4-2 lists the reaction zone length (i.e., the length of the zone between the shock wave and the CJ point) for various explosives. Table 4-3 lists the detonation pressure in the reacting zone for various explosives. The pressure of the Von Neuman spike can be explained by referring to figure 4-8. The point that the Rayleigh line crosses the unreacted explosive Hugoniot, V_F, corresponds to the high pressure in the Von Neuman spike. This is obviously at a higher pressure than the CJ point.

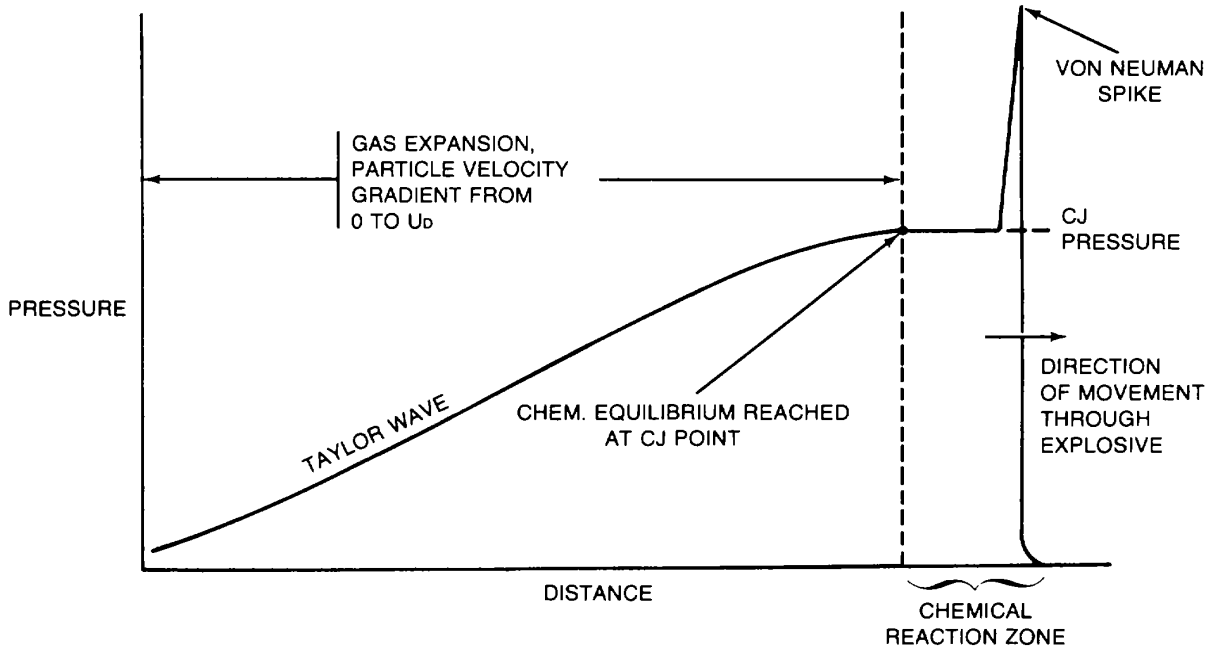


Figure 4-7. Detonation wave.

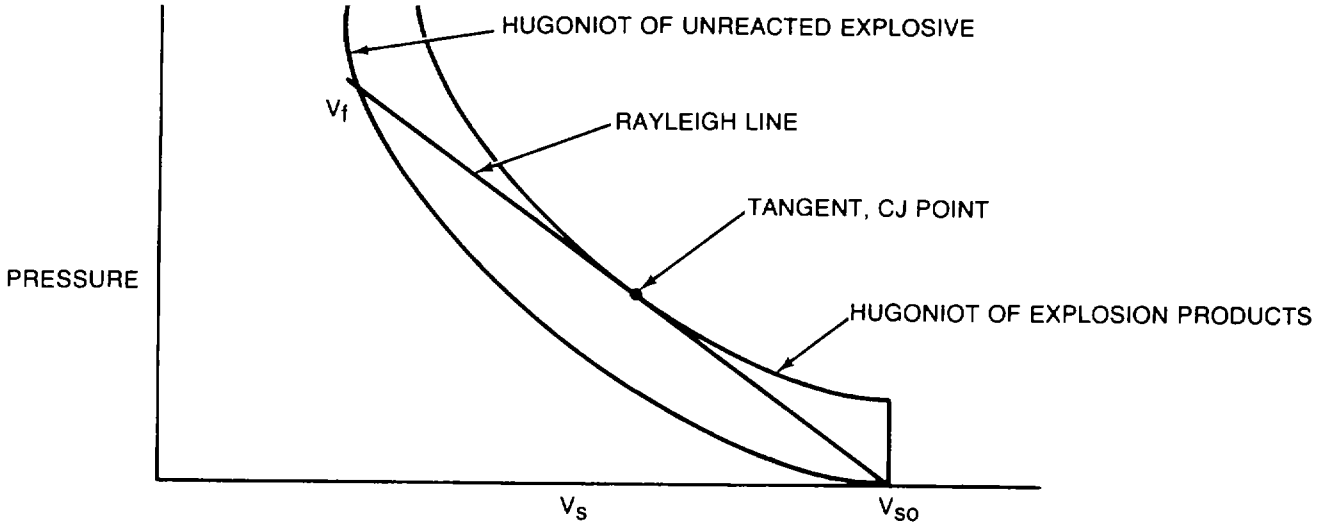


Figure 4-8. P-Vs plot during detonation.

Table 4-2. Reaction Zone Length

Explosive	Density, in grams per cubic centimeter	Approximate length, in millimeters
Amatol 80/20	1.67	4
Composition B	1.67	0.13
HBX-1	1.60	0.19
Nitroglycerin	--	0.21
RDX		0.826
(microporous)	1.30	1.82
(single crystal)	1.80	2.90
TNT		0.36
	1.00	0.32
	1.55	0.18
	--	0.13
	--	0.21
	1.59	0.70
(pressed)	1.63	0.3
(cast)	1.615	0.42 at 291°K
	1.70	0.55 at 77.4°K
	1.71	0.62 at 20.4°K
(liquid)	--	0.9 at 100°C
	--	1.1 at 100°C
TNT/RDX 50/50	1.67	0.12

d. Several computer programs are available that predict the detonation characteristics of a compound from basic chemical and physical properties. One such program is based on the Becker-Kistiakowsky-Wilson (BKW) equation of state. The BKW program requires information about the initial state of the explosive and about the state of the detonation products. The information required for the initial explosive is elemental composition, heat of formation, density, and formula weight. The information required for the detonation products is elemental composition, heats of formation, co-volumes (the effective size of the molecules), and fits of each products ideal gas entropy as a function of temperature. If any solid detonation products are present, the density, molecular weight, and an equation of state are required. From this information the BKW program computes the equilibrium composition of the detonation products at specified temperatures and pressures, the Hugoniot curve, the CJ pressure, the CJ temperature, the CJ density, the detonation velocity, and the isentrope of the detonation products through the CJ point. The values of pressures and temperatures obtained from the program agree to within 20 percent of the values observed experimentally and the detonation velocity agrees to within 10 percent. This margin of error is caused by the assumption of the BKW equation that detonation is steady state. To perform time-dependent flow calculations of the detonation process, other programs are used. These include SIN, EIC, 2DL, and 2DE. These programs require an equation of state of the detonation products (such as BKW), an equation of state for the unreacted explosive, an equation of state for mixtures of unreacted and totally decomposed explosive, and an equation of state that describes the rate at which the explosive decomposes into detonation products.

Table 4-3. Detonation Pressures

Explosive	Density in grams per cubic centimeter	Pressure in kilobars	
		Measured	Calculated
Composition B, grade A	1.717	295	--
Composition B-3	1.715	287	--
Composition C-4	1.59	--	257
Cyclotol 77/23	1.752	316	--
DATB	1.78	259	250
HBX-1	1.712	220.4	--
HMX	1.89	390	394
HNAB	1.60	205	--
HNS	1.60	--	200
LX-14	1.833	370	--
Nitrocellulose (12.0 % N)	1.58	--	200
Nitrocellulose (13.35 % N)	1.58	--	210
Nitroglycerin	1.59	253	251
Octol 77.6/22.4	1.821	342	--
Pentolite 50/50	1.70	--	255
PETN	1.77	335	332
PETN	1.67	300	280
PETN	0.99	87	100
RDX	1.767	338	348
TATB	1.88	--	291
Tetryl	1.71	--	260
TNT	1.63	210	223

4-6. Blast Effects. When a high explosive is detonated, the solid charge is rapidly converted to gaseous products. This process, which occurs in about 0.001 second, develops very high temperatures and pressures. Of the total energy available, as much as half may be used to expand the bomb casing and the remainder is used to compress the surrounding environment.

a. *Blast Effects in Air*.

(1) When an explosive charge is detonated in air, the gaseous products expand rapidly and compress the surrounding air. The air moves outward with high velocity, thus initiating a shock wave. This layer of compressed air is bounded by an extremely sharp front called the shock front in which the pressure rises abruptly. The shock front moves outward with an initial velocity much greater than that of sound but, after a short distance, the velocity decreases rapidly. The gaseous products of detonation move as a strong wind behind the shock front and are prevented by their own inertia from decreasing in velocity as rapidly as the pressure at the point of detonation decreases. As a result, a rarefaction effect is produced at this point and the pressure decreases. This condition of reduced pressure also moves outward, trailing the shock front. When the pressure becomes less than atmospheric, the wind reverses in direction and blows backward toward the point of detonation. Any light object, such as a leaf, when struck by the shock front, is rapidly carried away from the point of detonation and then is blown back almost to the original position when the wind reverses. The shock front, the high pressure area behind it, and the following rarefaction form a complete wave to which the terms blast and shock wave, generally, are applied (figure 4-9).

(2) While the duration of the positive pressure portion of the blast wave is about one-fourth that of the portion at less than atmospheric pressure, the amplitude of the pressure at the shock front is much greater than the amplitude of the decrease in pressure below atmospheric. The duration of the positive phase varies with the explosive charge and distance from the point of origin. In one case, the duration of the positive phase is of the order of 0.006 second at a distance of 15.5 meters from the bomb. A wall struck by such a blast wave is first pushed forward by the short, sharp, hammer-like blow of the positive pressure phase and then pulled backward by the much longer negative phase. Whether the wall falls forward or backward depends upon circumstances.

(3) Blast effect is measured by two criteria, peak pressure and impulse. Peak pressure is the pressure increase at the shock front or the highest pressure in the shock wave minus atmospheric pressure. Impulse is mathematically equal to the area under the time pressure curve for the duration of the positive phase (figure 4-9). This is approximately half the peak pressure multiplied by the duration of the positive phase. Peak pressure represents a measure of the maximum force exerted against a surface by a blast wave, since force is equal to the product of pressure and area. Impulse represents a measure of the force multiplied by the duration.

(4) As the shock front moves outward, the peak pressure decreases and the duration of the positive pressure phase increases. The rates of these changes vary with the magnitude of the peak pressure, but the net effect is decrease in impulse. With increase in distance from the bomb, impulse decreases approximately as the reciprocal of the radius.

(5) In general, two criteria must be satisfied in order to demolish any structure. Both peak pressure and impulse must exceed certain minimum values which depend upon the type of structure. Window glass requires a moderately high peak pressure but only a low impulse value since the positive pressure need not last long to cause fracture. On the other hand, a brick wall withstands only a small peak pressure, but the pressure must be of relatively long duration and therefore the impulse value must be high. The blast from almost any charge that develops sufficient peak pressure will have sufficient impulse to break glass. Most bomb charges that develop sufficient impulse to demolish a brick wall also develop sufficient peak pressure to do so. A general rule is that structures that are strong and light in weight, with respect to the area presented to the shock front, require high peak pressure but no great impulse for demolition. Heavy but relatively weak structures require considerable impulse but not such a high peak pressure.

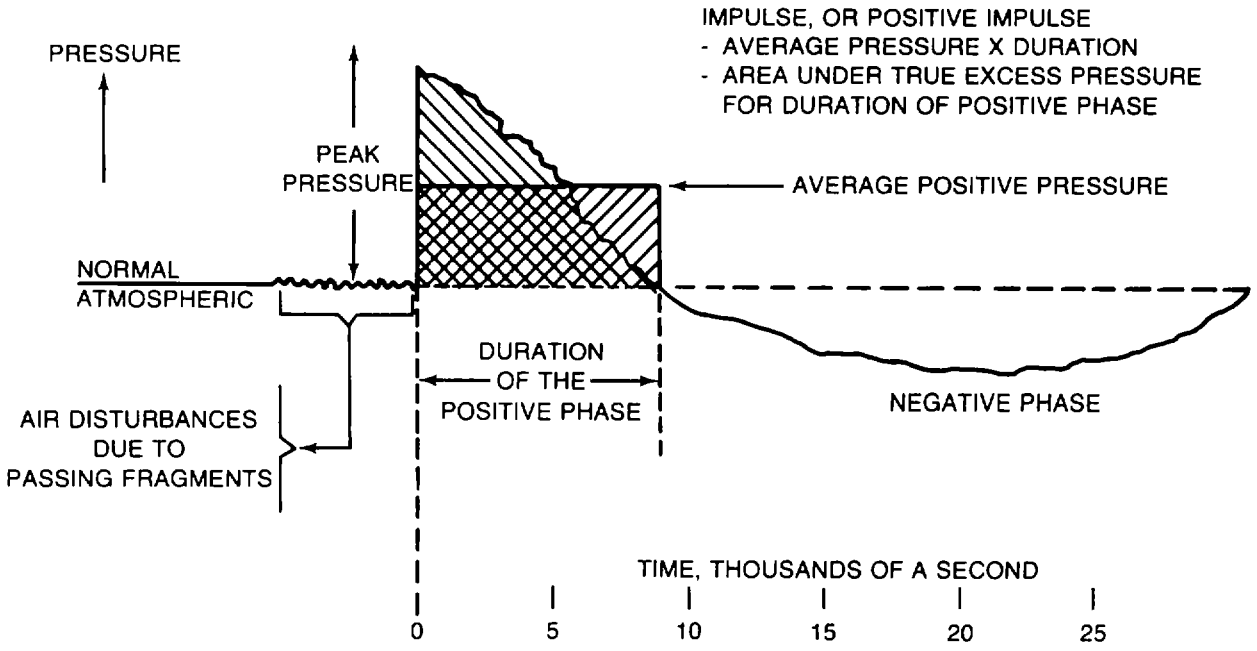


Figure 4-9. Typical pressure-time record for the blast from a bomb.

(6) Blast waves are reflected from solid surfaces but not in the same manner as sound and light waves are reflected. When the incident and reflected waves intersect on the ground, they do not make equal angles with the ground as do sound waves. Refer to figure 4-10. At small angles of incidence (the angle between the normal to the blast front and the normal to the reflecting surface), the angle of reflection is smaller than the angle of incidence, and the pressure behind the reflected wave is greater than behind the incident wave. Such reflection of a blast wave from a bomb that has detonated above the ground gives rise to an increased pressure wave at ground level. When the angle of incidence (a) is greater than an extreme angle (ae) (40 degrees for strong to a value approaching 90 degrees for very weak shocks), the incident and reflected waves do not intersect on the ground. This is known as irregular or Mach reflection. Reflection that occurs when the angle of incidence occurs at the extreme angle is known as the extreme regular reflection, whereas, reflection occurring where the angle of incidence is smaller than the extreme is known as regular reflection. When the incident angle exceeds the extreme angle, the reflected and incident waves intersect at some point above the ground. The lower portion of the reflected and the incident waves fuse into one wave which is known as the Mach stem (M, figure 4-10), the point of intersection being known as the triple point (TP, figure 4-10). The resulting existence of three waves, termed the Mach reflection, causes a density discontinuity and a region of high pressure termed the Mach region is formed. The pressure behind the front of the Mach region is approximately twice that of the incident wave. The top of this high-pressure region, the triple point, travels away from the reflecting surface. As pressure and impulse appear to have their maximum values just above and below the triple point, respectively, the region of maximum blast effect is approximately that of the triple point. The region of maximum blast effect is determined by the height above the ground at which the blast occurs. At distances that are large compared to the height of the burst, the incident and reflected waves have fused and proceed outward as a single shock. After the point of complete fusion of the waves, the shock wave is the same as one produced by a double charge detonated on the ground. As the distance from point of the blast increases, the Mach stem becomes normal to the ground.

(7) Blast effects are enhanced by confinement due to the reflection of blast waves by the confining surfaces. A blast wave traveling through a tunnel, corridor, trench, or even a street decreases in intensity much more slowly than in the open. If a bomb detonates within a building, there is considerable reflection of the blast wave from the walls, even if they are demolished. The rapid reflection of the wave from various walls, in such a case, results in a multiple punch effect on another wall. The overall effect of confinement is increased in the vulnerable radius of demolition of the bomb charge. The analogous vulnerable radius of visible damage (as detected by aerial observation) is also used to evaluate the effects of bombing.

b. Blast Effects Underground. An explosive charge, if detonated while buried, exerts pressure on the surrounding earth and causes movement effects over a distance known as radius of rupture. If the depth of burial is less than the radius of rupture, the explosion products blow through the surface of the ground and form a roughly circular depression known as a crater. An explosion on the surface of the ground makes a shallow crater which may be a greater diameter than that produced when the explosive is buried. This is due to the scouring action of gases projected downward from the explosive charge. Important factors in crater formation are the type of earth cratered and the type of explosive used. Explosives of a moderate charge in swampy ground make a relatively huge crater, while in a rock formation only a small crater will be formed. An explosive of low detonation rate that produces a large volume of gases, may form a larger crater than TNT if the charge is well below the surface and the ground is not too hard or rocky. If the charge is on the surface, a low-rate explosion makes a smaller crater than TNT because of the weaker scouring action of the lower velocity gases. If an explosive is buried at a depth exceeding the radius of rupture, the compression effect downward and horizontally and the lifting with subsequent subsidence cause a depression on the surface known as a camouflet.

c. Blast Effects Under Water. The detonation of high explosive under water results in shock waves of extremely high pressure which decay rapidly with distance from the charge. Since the total damage is due to both the shock wave and the subsequent bubble pulses, these effects must be separately evaluated. One measurement to make is that of the periods of oscillation of the bubble, that is, the time intervals between successive minima in the bubble radius. The length of the bubble period is related to the energy left after passage of the shock wave. In general, the longer the bubble period the greater the energy. A second measure of the energy may be obtained from a study of the maximum and minimum radii of the bubble. By a combination of radius and period measurements, energy calculations can be made.

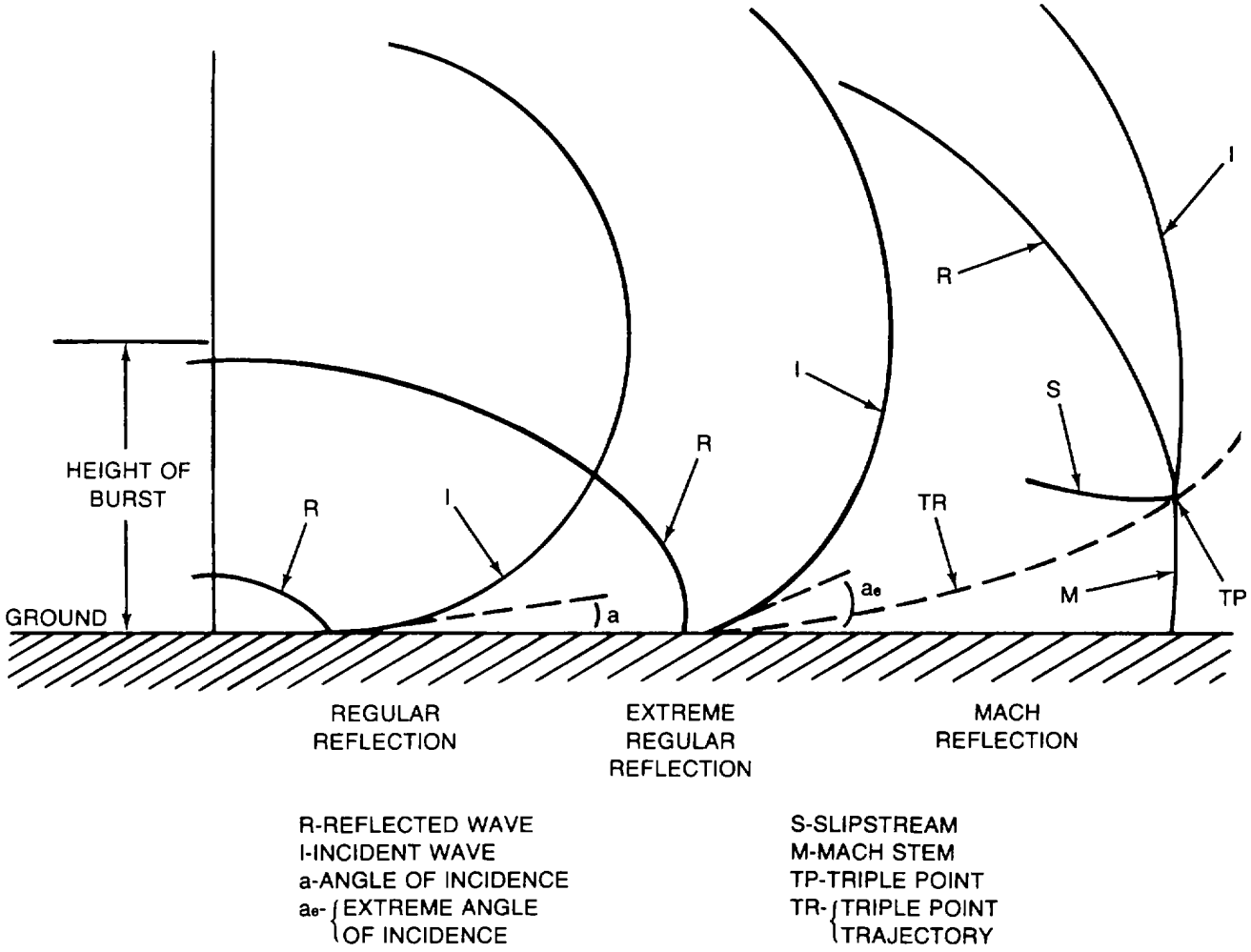


Figure 4-10. Mach reflection of blast wave.

4-7. Shaped Charge Effect. A shaped charge (figure 4-11) is a cylindrical explosive charge with a lined conical cavity in one end. The explosive is generally pressed or cast. The higher the detonation velocity and CJ pressure the more effective the shaped charge is. Very little effect is produced by explosives having rates of detonation less than 5,000 meters per second. The liner focuses the energy of detonation, thus enabling penetration of very thick and very hard targets such as armor.

a. As the charge explodes, the detonation wave passes over the liner. The liner material is accelerated somewhat normal to the explosive-liner interface (figure 4-12). Nearer the apex of the cone, the liner mass to charge ratio is lower so the velocity the liner material attains is higher. Also, nearer the apex of the cone, the metal liner does not have to distort as much as further down. This also causes the velocity to be higher toward the apex. When the liner material converges at the center line, or axis, of the charge, the surface material is squeezed out at high velocity. This material forms the jet. Since the material closest to the apex is at a higher velocity, the portion of the jet which comes from that area is also highest in velocity. Therefore, the jet has a velocity gradient. The material in the leading tip is moving faster than the material toward the rear. The remaining material, which is the bulk of the liner, forms a heavy slug which follows the jet at a much lower velocity. After traveling a distance of about five or six diameters of the original charge, the jet begins to break up because of the velocity gradient and inhomogenieties in the charge and liner. Inhomogenieties in the charge and liner cause the jet particles to have slightly different directions of flight.

b. The pressure applied by a shaped charge to a target is to the order of several megabars. This is well into the plastic range for almost all materials. Figure 4-13 illustrates the response of the target material to a shaped charge jet. Penetration occurs as the target material flows out of the hole. The material dislodged in the deeper parts of the hole flows out along the walls. Penetration is affected greatly by the distance of the base of the shaped charge to the target. This is called stand-off and is usually expressed in charge diameters. There is an optimum stand-off distance for maximum penetration. At closer distances, the jet has not fully formed and at further distances the jet is breaking up, causing the particles to hit off center such that they do not contribute to penetration. Generally the optimum stand-off is between two and six charge diameters. Penetration is normally around four to six diameters but could go as high as 11 to 12 diameters. The optimum liner thickness is about three percent of the charge diameter for soft copper. If a different material is used, the thickness should be determined by measuring the weight of soft copper that would be used for the particular charge diameter. This amount of material is then used. Liners made of less dense material will be thicker than the copper counterpart and liners made of more dense material will be thinner. Materials which are commonly used include copper, steel, glass, and aluminum. The angle of the cone apex varies from 42 degrees to 60 degrees in American ammunition and 18 degrees to 90 degrees in foreign ammunition. Forty-two degrees is the optimum angle for maximum penetration.

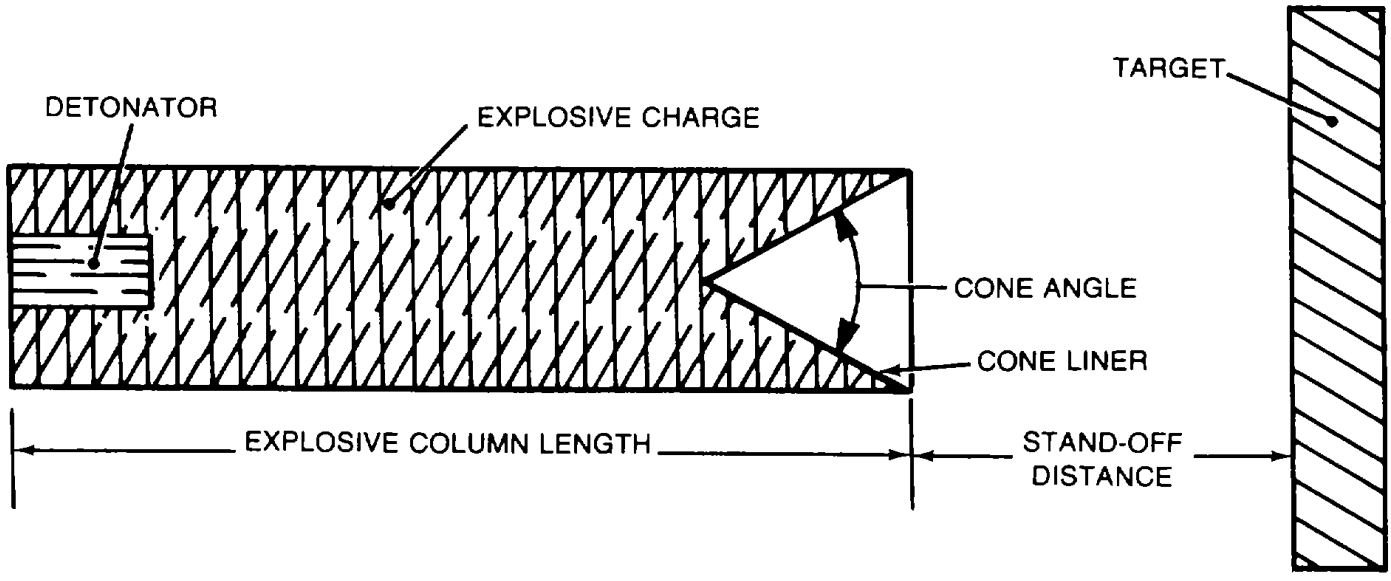
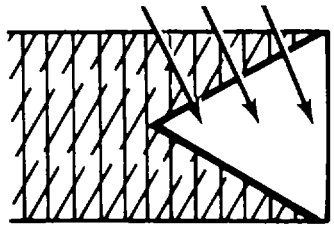
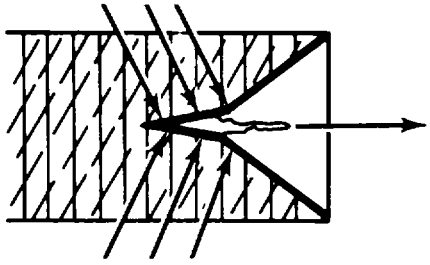


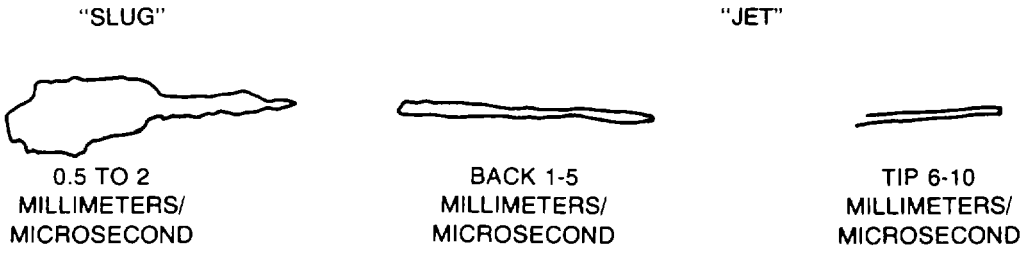
Figure 4-11. Shaped charge and target.



A. LINER IS ACCELERATED NORMAL TO EXPLOSIVE-LINER INTERFACE



B. MATERIAL IS SQUEEZED OUT TO FORM THE JET



C. SHAPED CHARGE JET

Figure 4-12. Shaped charge jet formation.

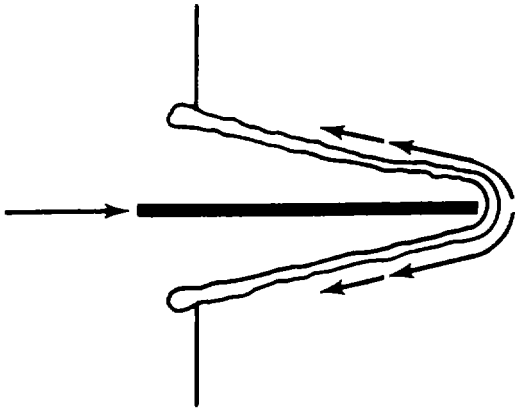


Figure 4-13. Shaped charge penetration.

c. When used in projectiles that rotate, shaped charge penetration is considerably reduced. Projectiles that have conical liners may lose as much as 50 percent of their effectiveness due to rotation. In general, penetration is reduced as spin increases from about zero to 200 revolutions per second, after which further increases have little effect. Rotating shaped charges produces holes of greater diameter than static charges, but rotation does not affect the volume of the hole produced. Changing the apex angle of the cone does not eliminate the reduction in penetration caused by rotation of the charge.

d. The United States uses one other geometry of shaped charge liner, hemispherical. A hemispherical liner produces comparable jet energies to a coneshaped liner. However, the velocity and mass distribution in the jet are different. Hemispherical liners turn inside out with almost all of the material projected in the jet. As much as 70 to 80 percent of the material in conical liner stays behind to form the slug. In hemispherical shaped charges, however, jet velocity is only about half of that obtained in a conical shaped charge. Hemispherical shaped charges are less sensitive to rotation than conical shaped charges.

CHAPTER 5

PROPERTIES AND TESTS OF EXPLOSIVES

5-1. General Requirements of Explosives for Military Applications.

a. *General*. Numerous compounds are explosive, however the number of compounds that can be used militarily is relatively small. This chapter describes the tests used to cull the usable explosives from the many that are unusable. Many explosive items are designed for a minimum lifespan of ten years. These tests are designed to characterize the explosive as much as possible before deployment to avoid problems during the user phase. The types of tests performed on each explosive depend, to a large degree, on the intended use of the explosive. Most of the tests yield data which are used to rank explosives relative to a standard explosive. The relative rank is then used to determine possible applications. Few tests have absolute ranges that explosives must fall into before use in military items is permitted.

b. *Availability and Cost*. In view of the enormous quantity demands of modern warfare, explosives must be produced from cheap raw materials that are nonstrategic and available in great quantity. In addition, manufacturing operations must be reasonably simple, cheap, and safe.

c. *Sensitivity*. A military explosive must be capable of being detonated and yet be as insensitive as possible. Military requirements for sensitivity are strict. Many compounds that detonate are not used as military explosives because of unfavorable sensitivity characteristics.

d. *Brisance and Power*. The brisance and power of an explosive determine applicability for specific purposes. A bursting charge must be brisant, but a ditching charge needs to be powerful and less brisant.

e. *Stability*. Military explosives must be able to withstand long periods of storage under unfavorable conditions. Storage conditions range from extreme heat and humidity in the tropics to the cold of arctic regions.

f. *Density*. The fixed volume available in a round of ammunition necessitates using explosives of maximum energy density. In general, the greater the density of the explosive the greater the energy available. This is not true, however, for some of the metalloorganic primary explosives. The high density of these compounds is caused by the presence of mercury or lead which does not add to energy content.

g. *Hygroscopicity*. Hygroscopicity, the property of absorbing moisture, can have an adverse effect on the sensitivity, stability, or reactivity of some explosives. Explosives which are hygroscopic must be loaded in moisture-proof containers. This extra precaution is generally undesirable, so explosives which are nonhygroscopic are used. Ammonium nitrate is an exception. Although very hygroscopi, the compound is extremely cheap and readily available.

h. *Volatility*. Volatility can cause loss by evaporation, development of pressure in rounds of ammunition, and separation of ingredients in composite explosives. These undesirable characteristics must be minimized in military explosives.

i. *Reactivity*. A military explosive must be as nonreactive as possible with the materials used in construction of munitions. Compatibility of specific explosives with these materials is discussed in Chapter 8. The reactions, which are accelerated by moisture in many cases, can cause liberation of gaseous products, loss of power, and loss of sensitivity. In some cases, such as with an azide and copper, the metallic salt formed can be dangerously sensitive. When the explosive is to be loaded in contact with or mixed with another explosive or binder, reactivity between the ingredients must be minimized.

j. *Toxicity*. Minimum toxicity is a desirable quality for any military explosive. A discussion of the toxicity of the explosives of military interest is presented in Chapter 12.

k. *Environmental Impact.* The impact of manufacturing and loading operations on the environment must be as small as possible.

l. *Demilitarization*. A military explosive should have favorable demilitarization characteristics. An example is plastic bonded explosives in which a thermally sensitive binder is used. Upon heating, the binder decomposes and the explosive may be totally recovered for reloading.

m. *Vulnerability and Safety* During Use. Explosives must be as invulnerable as possible to conditions that will be encountered during use. The explosives must also be as safe as possible during both manufacture and use.

5-2. Vacuum Stability Test. This test can be made at 100°, 120°, or 150°C or any other desired temperature, but a temperature of 100° or 120°C generally is employed. A weighed 1or 5-gram sample of the dried explosive is placed in a glass heating tube, so designed that the ground neck can be sealed with mercury after a calibrated capillary tube with a ground stopper end has been connected to the heating tube (figure 5-1). The lower end of the capillary tube is attached to a cup in which about seven milliliters of mercury are placed after the connection of the two tubes has been made. The system is evacuated until the pressure is reduced to about five millimeters of mercury. The level of the mercury in the capillary tube rises to near the top and its exact position is marked and recorded. The junction of the two tubes is sealed with mercury. The heating tube is inserted in a constant temperature bath maintained at the desired temperature ± 0.5°C. If an excessive amount of gas (11 + milliliters) is not evolved in less time, heating is continued for 40 or 48 hours. The tube is removed from the bath and cooled to room temperature and the level to which the mercury in the capillary tube has fallen is noted. The volume of gas liberated is calculated from the difference between the initial and final levels, the volume of the capillary per unit of length, the volume of the heating tube, and the atmospheric pressure and temperature conditions at the beginning and end of the test. Vacuum stability test yields reproducible values and when an explosive is subjected to this test at two or more temperatures, a rather complete picture of its chemical stability is obtainable. In some cases, tests at two or more temperatures are required to bring out significant differences in stability between explosives, but a test at 100°C is sufficient to establish the order of stability of an explosive. Vacuum stability test has been found suitable for determining the reactivity of explosives with each other or nonexplosive materials. This is accomplished by making a vacuum stability test of the mixture and determining if the gas liberated is significantly greater than the sum of the volumes liberated by the two materials when tested separately. When used for this purpose, the test generally is made at 100°C.

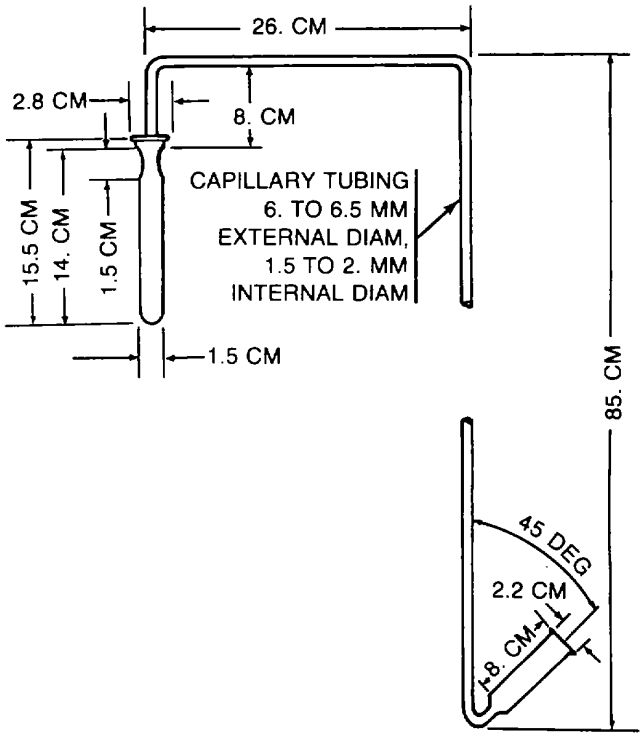


Figure 5-1. Vacuum stability test.

5-3. Impact Sensitivity. There are several different impact sensitivity machines in use. One type, the Explosive Research Laboratory (ERL) machine is shown in figures 5-2 and 5-3. The Picatinny Arsenal apparatus is shown in figures 5-4 and 5-5. The Bureau of Mines apparatus is shown in figure 5-6. The following discussion is relevant to the Bureau of Mines and Picatinny Arsenal apparatus. Sensitivity to impact is expressed as the minimum height of fall of a given weight required to cause at least one explosion in 10 trials, or the minimum height of fall of a given weight to cause explosions in 50 percent of the trials. In such tests, the explosive is ground so as to pass through a No. 50 sieve and be retained on a No. 100 sieve. In carrying out the test with the Picatinny apparatus, a steel die cup is filled with the explosive, covered with a brass cover, surmounted with a steel vented plug, placed in a positioned anvil, and subjected to the impact of a weight falling from a predetermined height. The minimum height, in inches, required for explosion is found after repeated trials. In making the test with the Bureau of Mines apparatus, 0.02 gram of the sample is spread uniformly on a hard steel block, over a circular area one centimeter in diameter. A hard steel tip of that diameter, imbedded in a

steel plunger, is lowered so as to rest on the explosive and turned gently so as to ensure uniform distribution and compression of the explosive. The plunger then is subjected to the impact of a weight falling from a predetermined height. When the minimum height required for explosion is found after repeated trials, this is expressed in centimeters. The Picatinny apparatus can be used for testing explosives having a very wide range of sensitivity, but the Bureau of Mines apparatus cannot cause the explosion of the most insensitive explosives and can be used only for testing explosives no less sensitive than TNT. The Picatinny apparatus can be used for testing solid or liquid explosives. The test with the Bureau of Mines apparatus can be modified so as to be applicable to liquid explosives. This is accomplished by using 0.007 to 0.002 gram (one drop) of the explosive absorbed in a disk of dry filter paper 9.5 millimeters in diameter.

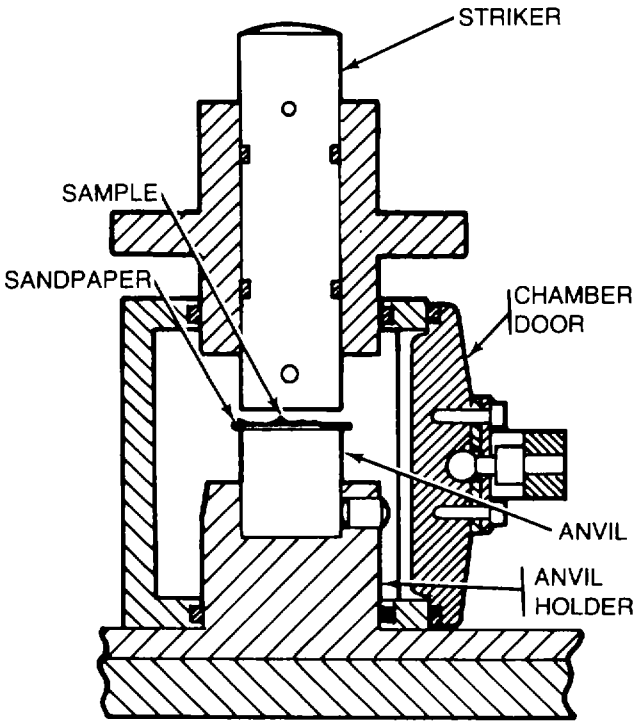


Figure 5-2. Anvil striker arrangement, ERL machine.

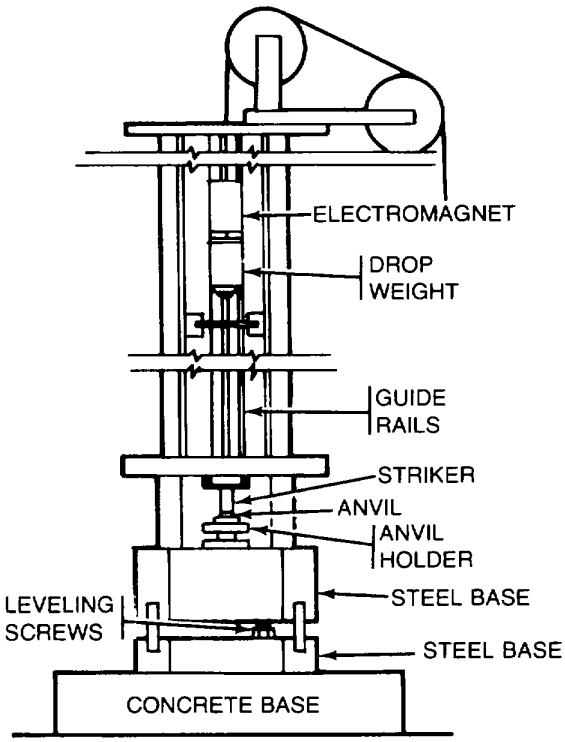


Figure 5-3. Drop weight impact machine, ERL type, type 12 tools.

5-4. Electrostatic Sensitivity. At the present time more than one method is used to determine electrostatic sensitivity. In all of the methods a spark gap is formed between an electrode and the explosive sample. A capacitor is charged to a specific voltage then discharged through the gap. Both the size of the capacitor and the voltage are varied to vary the energy in the spark. Compounds which deflagrate or detonate at spark energy levels less than 0.25 joules are not acceptable.

5-5. Detonation Velocity. Detonation velocity can be determined in any of several ways; the choice of a method probably depends more on the availability of equipment and well tested procedures than on any inherent advantage of a given method.

a. *Chronographic Method*. The chronographic method is widely used. This method depends on the closing of switches either by the conduction of hot gases between two electrodes or by the forcing together of two electrodes by the pressure induced by the detonation. Precision of the measurements depends on the number of switches or pins that is used on the charge and on the precision of the equipment.

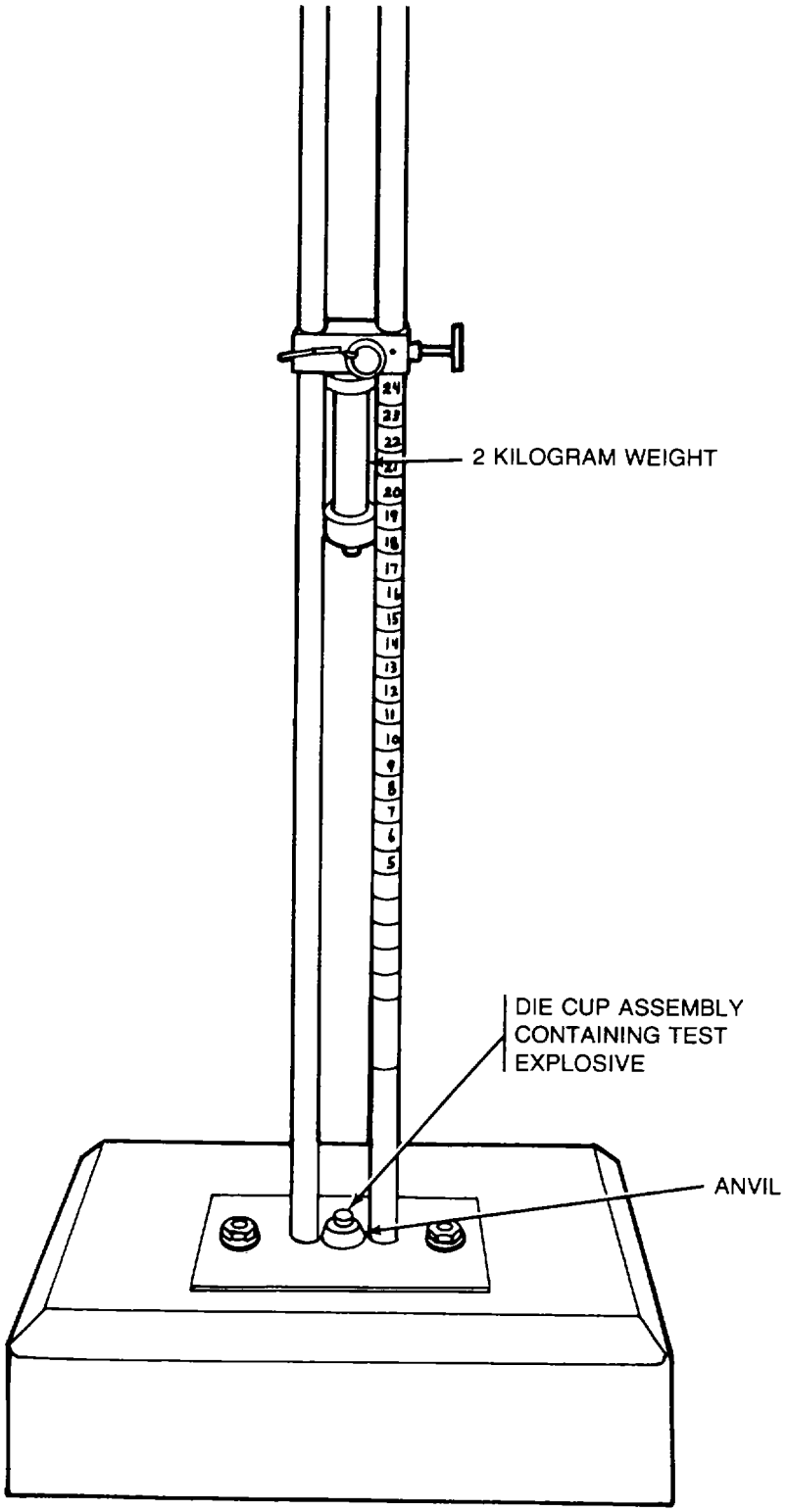


Figure 5-4. Picatinny Arsenal impact test apparatus.

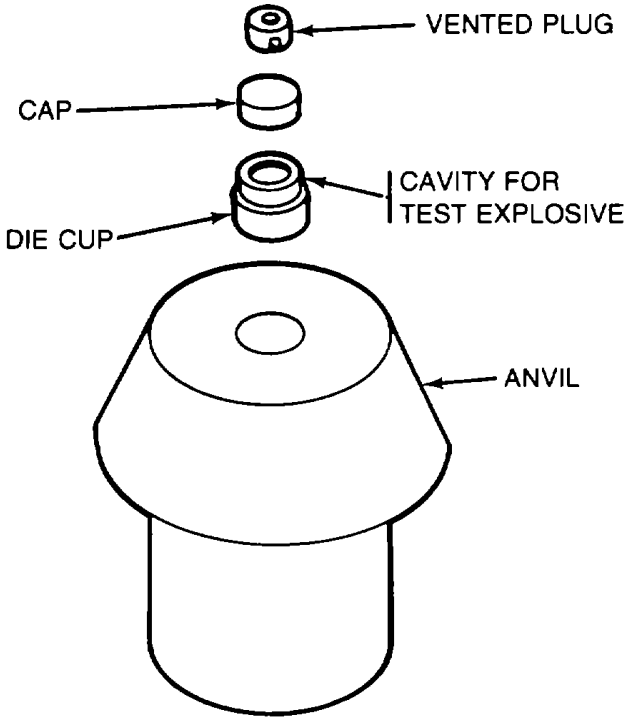


Figure 5-5. Parts of Picatinny Arsenal test apparatus.

b. *Electronic Method*. Another method, which is also entirely electronic, depends on embedding a resistance wire in the explosive. A constant current is maintained in the resistance wire and the return path, which may be a nearby embedded copper wire, a wire or foil on the surface of the charge, or a metal case if the charge is confined. The voltage across the resistance wire is recorded on an oscilloscope. This voltage decreases as the detonation moves along the wire and effectively shortens the wire. This method gives, in effect, the instantaneous position of the detonation front so that the slope of the trace on the record from the oscilloscope is proportional to the detonation velocity. A closely related technique uses a resistance wire which is wound on an insulated wire or other conducting core. These methods are not recommended for pressed charges. The precision of either version of the resistance technique depends on the quality of the charges, the precision of making the probes, and the precision of the electronics. For smaller diameter charges, the probes and wires may perturb the detonation front so that a true value of the detonation velocity cannot be obtained.

c. *Optical Method*. A commonly used optical method makes use of the streak or smear camera to record the instantaneous position of the detonation front. Because the record gives the instantaneous location of the detonation front, the slope of the streak is proportional to the velocity. Simple data reduction techniques can be used for the application discussed here. The traces are straight so that after digitizing, the data are fitted with a linear relation, the coefficient of the time being the velocity of the detonation. Again, this method can be made to give precise results if sufficient care is taken in preparing the charges and in arranging the experiment.

5-6. Cook-Off Temperature. To determine the cook-off temperature, a sample of approximately five milligrams is placed on a melting point bar. The cook-off temperature is the lowest bar temperature at which the sample flashes off.

5-7. Friction Sensitivity. Friction sensitivity tests are made to determine the relative safety of an explosive during processing. The test may be run on any of several types of machines. In the Picatinny apparatus, a 20 kilogram shoe with an interchangeable face of steel or fiber is attached to a pendulum. The shoe is permitted to fall from a height of one meter and sweep back and forth across a grooved steel friction anvil. The pendulum is adjusted to pass across the friction anvil 18+1 times before coming to rest when no explosive is present. A seven gram sample of the explosive is then spread evenly in and about the grooved portion of the friction anvil, and the shoe is allowed to sweep back and forth over the anvil until it comes to rest. Tests of 10 portions of the sample are made, and the number of snaps, cracklings, ignitions, and/or explosions is noted. As the steel shoe is the more effective in causing explosions, tests with the fiber shoe sometimes will show differences between explosives indicated by the steel shoe to be of the same degree of sensitivity.

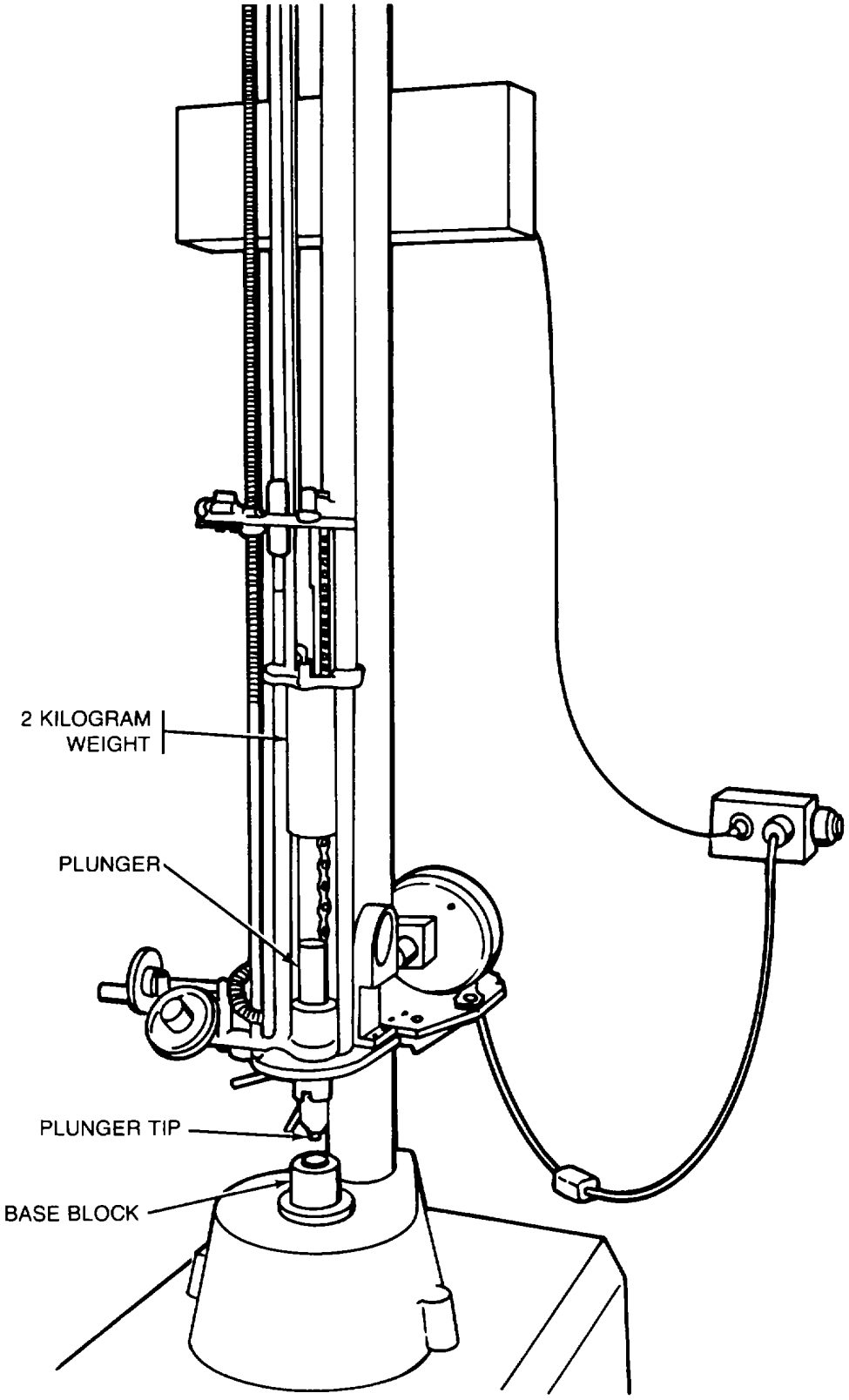


Figure 5-6. Bureau of Mines impact test apparatus.

5-8. Gap Tests. The gap test is used to measure the sensitivity of an explosive material to shock. The test results are reported as the thickness of an inert spacer material that has a 50 percent probability of allowing detonation when placed between the test explosive and a standard detonating charge. In general, the larger the spacer gap, the more shock-sensitive is the explosive under test. The values, however, depend on test size and geometry and on the sample (the particular lot, its method of preparation, its density, and percent voids). Gap test results, therefore, are only approximate indications of relative shock sensitivity. Tests have been developed covering a wide range of sensitivities for solid and liquid explosives at Los Alamos National Laboratory (LANL), Naval Surface Weapons Center (NSWC), Mason & Hanger-Silas Mason Co., Inc., Pantex Plant (PX), and Stanford Research Institute (SRI). The test configurations are briefly described below. In all cases, detonation of the acceptor charge is ascertained by the dent produced in a "witness plate." While there are many more potential gap test geometries, these are the test configurations for which results are reported in this manual.

a. *NSWC Small Scale Gap Test (SSGT).*

Donor	25.4 millimeters (1 inch) outer diameter x 38.1 millimeters (1.5 inches) long RDX pellet.
Acceptor	25.4 millimeters (1 inch) outer diameter x 38.1 millimeters (1.5 inches) long.
Spacer	25.4 millimeters (1 inch) diameter Lucite disks of different thicknesses.

Results are reported in millimeters.

b. LANL Small Scale Gap Test (SSGT).

Donor	Modified SE-1 detonator with PBX-9407 pellet 7.62 millimeter diameter x5.26 millimeters long (0.0300 inch x0.207 inch).
Acceptor	12.7 millimeters diameterx38.1 millimeters long (0.5 inchx1.5 inches).
Spacer	Brass shims in 2.5 millimeter (0.1 inch) increments.

Results are reported in millimeters.

c. LANL Large Scale Gap Test (LSGT).

Donor	41.3 millimeters diameter x102 millimeters long (1.625 x4 inches) PBX-9205 pellet.
Acceptor	41.3 millimeters diameter x 102 millimeters long (1.625 x4 inches).
Spacer	41.3 millimeters diameter (1.625 inches) disks of 2020-T4 Dural (aluminum).

Results are reported in millimeters.

d. *PX Gap Test*.

Donor	25.4 millimeters diameterx38.1 millimeters long (1 inch x1.5 inches) LX04 pellet.
Acceptor	25.4 millimetersx25.4 millimeters (1 x 1 inch) right cylinder.
Spacer	25.4 millimeter (1 inch) diameter brass shims in 0.25 millimeter (0.1 inch) increments.

Results are reported in millimeters.

5-9. Flying Plate Test. The flying plate test is used to measure the vulnerability of an explosive to high velocity impact. A steel plate is propelled by the detonation of an explosive at the sample under test. The velocity of the plate is adjusted by varying the size of the explosive charge.

5-10. Transportation Vibration. This test is performed on an end item to determine if the explosive is satisfactory for that specific application. The test consists of vibrating explosive components according to a specified schedule of frequencies, amplitudes, and durations while being maintained under prescribed temperate conditions.

5-11. Temperature and Humidity. This test consists of exposing end items containing explosives to conditions of cycling temperature and humidity.

5-12. Jolt. In this test an end item containing explosives is attached to the end of a pivoted arm. The arm is raised to a prescribed height and allowed to drop freely. The end item strikes a leather padded anvil. The test is repeated a prescribed number of times with the end item in a number of different orientations to the anvil.

5-13. Jumble. In this test an end item containing explosives is placed in a wood lined steel box. The box is then rotated about two diagonal corners at a speed of 30 revolutions per minute. The rotation is continued for 3,600 revolutions.

5-14. Forty Foot Drop Test. In this test, explosive components, such as bombs, are dropped 12.2 meters (40 feet) onto a hard impact surface. The impact surface consists of a steel plate on a concrete pad. The impact area is surrounded by walls of sufficient height and strength to contain the component during rebound. The component is dropped a number of times so different areas of the item are exposed to the impact. This test is used to determine the safety of both the component case and the contained explosive. No cracks, breaks, deformation, or displacement should occur in the component case. No explosion, burning, or charring of the explosive should occur.

5-15. Growth and Exudation Characteristics.

When explosives contain liquids as impurities, they often undergo irreversible dimensional changes when subjected to many temperature cycles between 54°C and + 71°C. In explosives containing TNT, the dinitrotoluenes form low-melting liquid eutectics which cause problems. Mononitrotoluenes added as anti-cracking agents give large irreversible growth in TNT explosives. In the use of pure TNT explosives, one solution to the cracking problem is the use of pure TNT with addition of high melting point eutectic formers which reduce cracking without introducing objectionable irreversible dimensional change during the normal temperature variations encountered. Another cause for irreversible dimensional change is the solid polymorphic transition such as occurs with ammonium nitrate. (Refer to ammonium nitrate in Chapter 8.) Procedures for solids include measuring any cylindrical sample at least 1.27 centimeters in diameter by 1.27 centimeters in height, temperature cycled between -54°C and +60°C for 30 cycles or more. If no exudation or excessive growth is noted, an additional test can be made for exudation by placing two cylinders together inside a sealed can. These should be held together by parallel steel face plates and clamped together at an initial pressure of 413.7 kilopascals. The sealed unit is subjected to 30 cycles from ambient to 140°F, maintaining each temperature long enough for the entire sample to reach the temperature of the oven. The sample is then observed for exudation. Any exudate is removed and weighed.

5-16. Rifle Bullet Impact Test. Rifle bullet impact tests may use a .30 or .50 caliber bullet. Results reported in this manual use a .30 caliber bullet. In the.30 caliber test a bomb is prepared by screwing a closing cap to one end of a piece of cast iron pipe 7.62 centimeters long, 5.08 centimeters in diameter, and threaded at both ends. The bomb is filled with the cast, pressed, or liquid explosive and is closed by screwing on a closing cap. With the loaded bomb in a vertical position, a caliber .30 bullet is fired through it from a distance of 30 yards, so that the bullet strikes between the two closing caps and at a right angle to the axis of the bomb. Five or more such tests are made and the percentage of explosions is noted. Those explosives which do not detonate, deflagrate, or burn are considered highly desirable. Those which burn but do not detonate are still generally satisfactory, but those which detonate are used only in applications where detonation from projectile impact is unlikely because of protection, high altitude release, or other considerations.

5-17. SUSAN Test. The SUSAN Sensitivity Test is a projectile impact test. The projectile head contains about 0.45 kilograms of explosive and the target is armor-plate steel. Figure 5-7 shows the projectile used in this test. The results of the tests are expressed as a sensitivity curve in which the relative point-source detonation energy released by the explosive on impact is plotted as a function of the projectile velocity. The relative point-source detonation energy can be derived from a transit-time measurement of the air shock from the point of impact to a pressure gauge three meters (10 feet) from the point of impact. The results determined in this manner are somewhat subjective, particularly when the reaction level shows a large but relatively slow increase with time. The currently preferred way to determine the point-source detonation energy is to relate it to the overpressure measured by the pressure gauge. This method gives much more reproducible data and is not subject to many of the errors of the transit-time measurements. On the figures in Chapter 8, the energy scale ranges from zero (no chemical reaction) to about 100 for the most violent detonation-like reactions (all explosive consumed). Less violent burning reactions that appear to consume all of the explosive can give values as low as 40, whereas the energy equivalent of TNT fully reacted as a point source would be 70. In the test material of Chapter 8 details of the impact process pertinent to the impact safety of an explosive are given. Remarks about probabilities of large reactions are relevant to unconfined charges in the 11 kilogram (25 pound) class. Smaller unconfined charges show a trend of decreasing reaction level as the charge size decreases. References to the "pinch" stage of impact refer to the terminal stage of the test when the nose cap has completely split open longitudinally and has peeled back to the steel projectile body, which is rapidly brought to a halt.

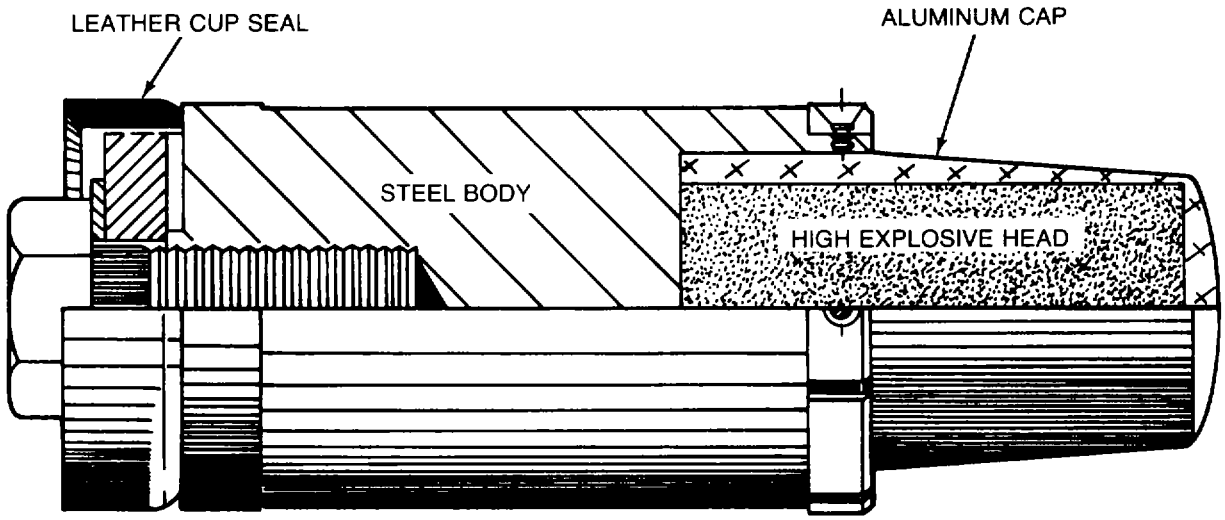


Figure 5-7. Scaled drawing of the SUSAN projectile. The high explosive head is 4 in. long and 2 in. in diameter (102 m x0.051 m).

5-18. Skid Tests. A combination of friction and impact is a frequent cause of accidents where large pieces of an explosive can be dropped a few feet. The skid test measures the sensitivity of an explosive material hitting a rigid surface at glancing angle. In one testing configuration a sample of the explosive is dropped vertically onto a hard surface inclined at 45 degrees. In another testing configuration the explosive sample is attached to the end of a pendulum. The pendulum is allowed to swing from a predetermined height.

5-19. Adiabatic Sensitivity Test. In the adiabatic sensitivity test a sample of the explosive is placed in an airtight holder. The top of the holder has an air compressing piston that decreases the volume and thus increases the pressure in the test chamber when struck by a falling weight. The results of the test are reported as the height the weight must fall, thus the degree of compression, to produce detonation in 50 percent of the cases.

5-20. Fragmentation Test. In the fragmentation test a charge of the explosive under test is loaded into a cylinder or artillery shell and detonated in a pit filled with sand or sawdust. The fragments are separated magnetically and categorized by weight. This test also gives an indication of the brisance of the explosive.

5-21. Cylinder Expansion Test.

a. An important problem faced by the designer of fragmentation warheads is that he must maximize the energy which is transferred from explosive to metal during the detonation. The most frequently encountered configuration is that of an explosive-filled metal cylinder detonated by a wave moving axially. The best scaling law that has been devised for this condition is that of Gurney, who disregarded detonation conditions and shock effects in the metal and assumed implicitly that all the energy of the explosive is conserved. His equation for the cylinders is

$$v = \sqrt{2E\left(\frac{C/M}{1+0.5\,C/M}\right)}$$

where v is the velocity to which the metal is accelerated by the explosive, E is unit energy content of the explosive, C is the weight of the explosive, and M is the metal weight. This expression of velocity in terms of C/M implies that weight-ratio scaling of explosive and metal is of prime importance and that dimensional scaling need not be considered at all. The term $2E$ has the dimensions of a velocity as was pointed out by Gurney in his original report.

b. Determination of the Gurney constant of a warhead explosive is made in the cylinder expansion test where the explosive contained in a metal cylinder is end-detonated and the maximum lateral velocity of the metal is measured. The geometry resembles that of most fragmentation warheads, particularly as to lateral confinement of the explosive. The dimensions of the cylinder can be chosen so as to give the full run-up to detonation velocity before reaching the location of fragment velocity measurements, and the end-release effects can be kept far enough downstream so as not to affect fragment velocities. Other techniques for evaluating explosives, while of full value in their own contexts, are all less applicable to the prediction of effects in the fragmentation warhead. The plate-push test transfers only about one-fourth as much of the energy of the explosive to the metal as does the cylinder expansion; also, the air cushion between explosive and plate is highly unrepresentative of the warhead configuration. Other rating tests such as the plate dent, ballistic mortar, and the Trauzl lead block are even more unrepresentative geometrically.

c. The cylinder expansion test is any test performed where a metal cylinder (relatively thin walled) is loaded with an explosive and this explosive charge is detonated. As the detonation occurs, the expansion of the cylinder wall is observed and recorded in such a way that the rate at which the wall moves outward can be followed up to the point where the expanding cylinder wall is obscured by the reaction products as they break through the wall.

d. The method for observing the wall's expansion varies. It has been recorded through the use of electronic pin probes and raster oscilloscope recording systems as well as with flash X-ray techniques. It has also been accomplished by the use of streak cameras and framing cameras. The Lawrence Radiation Laboratory method uses a streak camera for the recording of the wall velocity and a pin probe method for determining the detonation velocity of the explosive while it is expanding the walls of the test cylinder. The Atomic Weapons Research Establishment, UK, uses both electronic pin probe and streak camera methods to record the wall expansion, and pin probes for the detonation velocity. There is some reason to believe that, perhaps in the early stages of the expansion, the pin probe method may be more accurate, but the data reduction is also a bit more difficult in some respects than with the streak camera record.

e. When various explosives are rated in the standard geometry, the relative performance of these explosives becomes readily apparent. This permits the warhead design engineer to select an explosive compound for a specific feature of its performance.

f. It has been demonstrated that cylinder expansion test results scale up or down over a wide range of sizes.

CHAPTER 6

PROPERTIES AND TESTS OF PROPELLANTS

6-1. Introduction. The tests performed on propellants can be divided into three classes: mandatory, prescribed, and optional. The mandatory tests, covered in paragraphs 6-2 through 6-13, are safety tests. These tests must be run on each propellant formulation. The prescribed tests, covered in paragraphs 6-14 through 6-17, provide useful information about a propellant formulation. These tests are generally run on propellant formulations after the mandatory tests. The optional tests, covered in paragraphs 6-18 through 6-23, are only run if warranted by the intended application of the propellant formulation. Tests in which a propellant formulation is heated are called accelerated aging tests.

6-2. Compatibility. Compatibility can be measured by any of three methods: Taliani test, vacuum stability test, and differential thermal analysis. The propellant and the inert material being tested for compatibility are mixed together in some ratio which may vary from equal parts of propellant and test material to 10 parts propellant and 1 part inert material. In the vacuum stability test, increased reactivity is indicated by the mixture evolving more than five milliliters of gas over the sum of the amount of gas produced by the ingredients tested separately. In a differential thermal analysis, increased reactivity is indicated by an upward displacement of the curve. In the Taliani test, increased gas production also indicates more reactivity. Increased reactivity is considered evidence of incompatibility.

6-3. External Heat. In this test, also called the bonfire test, the propellant formulation is loaded into a standard cartridge assembly or storage container. The sample is mounted 30.5 centimeters (one foot) above a fire which is allowed to burn for 30 minutes. The test is recorded using a 16 millimeter movie camera. The film record of the test is examined to determine if any detonation occurred. No detonation reaction is considered the acceptable criteria for a propellant formulation.

6-4. Deflagration to Detonation Transition. In this test, an igniter is placed in the bottom of a tall test container which is then filled with the sample material. Propellants must not undergo detonation when ignited in this manner.

6-5. Heat Tests. Heat tests are performed at 1 34.5°C for single-base propellants and 1 20°C for double-and triple-base propellants. These tests measure the stability of the propellant Specimens of the propellant are placed into the bottom five centimeters (two inches) of a glass test tube. A piece of methyl violet indicator paper is placed vertically in the tube so that the lower end of the paper is 25 millimeters from the specimen. The tube is corked and set into a constant temperature block or a constant temperature reflux bath. The temperature must be maintained to within 0.5°C. The result of the test is reported as the time required for the test paper to change color to salmon pink. For the propellant to pass the test, the color change cannot occur in less than 40 minutes or 60 minutes, depending on the propellant formulation, and the sample may not explode in less than five hours.

6-6. Vacuum Stability. Vacuum stability tests are performed at 100°C for single-base propellants and 90°C for double-and triple-base propellants. This test determines propellant stability on the basis of the volume of gas liberated on heating the propellant under vacuum. The propellant specimen is placed in a heating tube which is then connected to a capillary tube. Mercury is placed in a cup on the other end of the capillary tube. The system is then evacuated to approximately five millimeters. The mercury is then allowed to enter the capillary. The heating tube is then placed in a constant temperature reflux bath. The volume of gas liberated during the test is determined by observing the mercury level. If rate data is desired, the volume of gas is observed at regular intervals. If the volume of condensable gases is desired, the volume of gas is calculated based on measurements before the tube is removed from the constant temperature bath. Although there is no specific pass-fail criteria established for this test, the test is stopped when the gas volume reaches 11 +mil.

6-7. Closed Bomb. The standard closed bomb is a thick-walled cylindrical vessel capable of withstanding gun pressures. The bomb is equipped with firing electrodes to affect ignition, a pressure transducer, a gas release valve, a thermocouple, and temperature controlled water jacket. The result of the test is a pressure time plot. There is no pass-fail criteria for this test.

6-8. Surveillance. In the surveillance test, a 45 gram sample of the propellant is placed in a 237 milliliter (eight ounce) glass, stoppered bottle which provides an essentially airtight seal. The bottle consists of a special colorless resistance glass which has no more than 0.02 percent alkalinity calculated as potassium hydroxide. The test is performed at 65.5°C. The bottle and contents are placed in a chamber and the temperature is regulated to within one degree centigrade. After 24 hours of heating, the stopper is reseated. Daily observations are then made to check for the appearance of reddish fumes which indicate the presence of oxides of nitrogen. Single-base propellants, when new, should last for fifteen hundred days before fuming. Double-base propellants should last at least 400 days. This test does not yield reliable data for triple-base propellants. For these propellants, the stabilizer content is analyzed at regular time intervals. The rate of stabilizer depletion gives an indication of the maximum storage life of the propellant. A stabilizer depletion test can also be performed on single-and double-base propellants.

6-9. Card Gap. The card gap test measures the sensitivity of a propellant formulation to detonation by a shock wave. A sample of the propellant is placed in a cardboard tube with a booster explosive. The explosive and sample are separated by a series of 0.254 millimeter (0.01 inch) cellulose acetate cards. The test results are reported as the number of cards necessary to prevent detonation of the sample. Three successive trials with no detonation are required. Seventy cards represent the dividing line between an explosive and fire hazard material.

6-10. Cap. This test determines whether a propellant formulation can be detonated by a shortened number eight blasting cap. The sample and blasting cap are placed on top of a lead cylinder. Whether a detonation occurs is determined by the degree of compression of the cylinder. The test results are reported as either a detonation, sample burned, sample fragmented but no reaction, or no reaction. To pass this test, the propellant must not detonate.

6-11. Electrostatic Discharge Sensitivity. This test determines the sensitivity of a propellant formulation to energy from an electrostatic discharge. A test sample of not more than 50 milligrams is placed on a test plate. A capacitor is charged to the desired energy level with a 5,000 volt power source and discharged into the sample through a steel needle. Results are reported as the maximum energy which can be applied without decomposing the sample. Twenty consecutive negative results are required at the specified energy level. High sensitivity material yields results in the range of 0.001 to 0.00875 joules, medium sensitivity material in the range of 0.00875 to 0.0125 joules, and low sensitivity material in the range of 0.0125 to 12.5 joules.

6-12. Friction Sensitivity. This test is performed on an apparatus which consists of a metal sliding block, a stationary metal wheel that is attached to a hydraulic ram, and a weighted pendulum. The sample, amounting to no more than 50 milligrams, is placed on the block under the wheel. Pressure is applied using the hydraulic ram. The pendulum is raised to a 90 degree position and dropped. Results are reported as the maximum force which can be applied to the wheel without causing the sample to decompose. Normally, 20 consecutive negative results must be obtained. The results of this test are compared to those obtained for other propellants. Most standard propellants have values of about 4,360 Newtons.

6-13. Impact Sensitivity. This test may be performed on any of the standard impact sensitivity devices. The results of the test are compared with data obtained for other standard propellants.

6-14. High Loading Rate Compression. In this test, propellant grains are subject to compressive loading at about the same rate and in the same time frame as occurs in the chamber during firing. The propellant grains are machined to give flat parallel ends with a length to diameter ratio of approximately one. The machined samples are compressed perpendicular to the flat ends using a high rate hydraulic servo. The servo is computer controlled. The results of the test are the maximum compressive strength, the strain at the maximum compressive strength, stress-strain curves, the time to maximum compressive strength, and whether the mode of failure was brittle or ductile. A drop tower apparatus may also be used to obtain higher strain rates.

6-15. Low Loading Rate Compression. For this test, propellant grains are machined to give flat parallel ends usually with a length to diameter ratio of one. Solid grains are usually extruded to yield a diameter of approximately 1.27 centimeters (0.5 inches). The device used for this test is a mechanically driven, electronically controlled tester capable of continuously recording the load exerted on a test specimen. The compressive effect on the sample is also measured. The result of the test is a load-displacement curve. From this curve the strain at maximum compressive strength and maximum stress are computed.

6-16. Taliani. The Taliani test is used to determine the stability of a propellant. A dry sample of the propellant is placed in a tube, heated to a specified temperature (usually 110°C), and the tube is evacuated. The composition of the atmosphere above the sample is controlled by alternately filling with nitrogen or another gas and evacuating a specified number of times. The pressure is then reduced and heating is continued. The pressure in the tube is measured with a manometer. The increase in pressure as the test progresses is a measure of the rate of decomposition of the sample. The test result is a graph of the time versus the pressure in the tube. The following data is usually reported: the time in minutes required for the pressure to reach 100 millimeters of mercury, the slope of the line at 100 millimeters of mercury, and the slope of the line at 100 minutes.

6-17. Explosion Temperature. In this test, a sample of the propellant formulation is loaded into a gilding metal tube and then immersed in a woods metal bath which has been raised to a specified temperature. The time to ignition is recorded. Ignition is detected by noise, flash, or smoke. The ignition time is obtained at several temperatures. A time-temperature plot is made. The result that is reported, the temperature required to ignite the propellant in five seconds, is obtained by extrapolation of the time-temperature plot.

6-18. Strand Burner. In this test a strand of propellant that is 17.8 centimeters (seven inches) long and 3.2 millimeters (one-eighth of an inch) in diameter is placed in a bomb in which the temperature and pressure can be regulated. The strand is placed vertically in a jig and ignited at the top. Vertical burning is ensured by coating the strand with a compound that does not interfere with the burning of the propellant. Two wires are inserted through the jig, one 6.4 millimeters (one-quarter of an inch) from the top of the strand and the other 12.7 centimeters (five inches) below the first. As the propellant burns, an electronic circuit through the two wires is broken and an automatic timer is used to determine the burning time. The rate is calculated from the strand length and burning time. The effect of initial temperature and pressure on the burning rate is measured.

6-19. 90°C Dutch Weight Loss Test. In this test, a four gram sample of a propellant is placed in a stoppered tube and inserted in a heating block which is maintained at 90°C. Every second day the stoppered tube is removed and cooled to room temperature for 30 minutes. The stopper is then briefly lifted and closed again. The tube is weighed to the nearest milligram and reinserted in the heating block. The test results are then plotted as weight loss percentage versus the time in days, as shown in figure 6-1. The initial bump in the curve, which results from loss of volatiles, is ignored. The results reported are the number of days coinciding with the kink in the curve, which indicates the onset of instability.

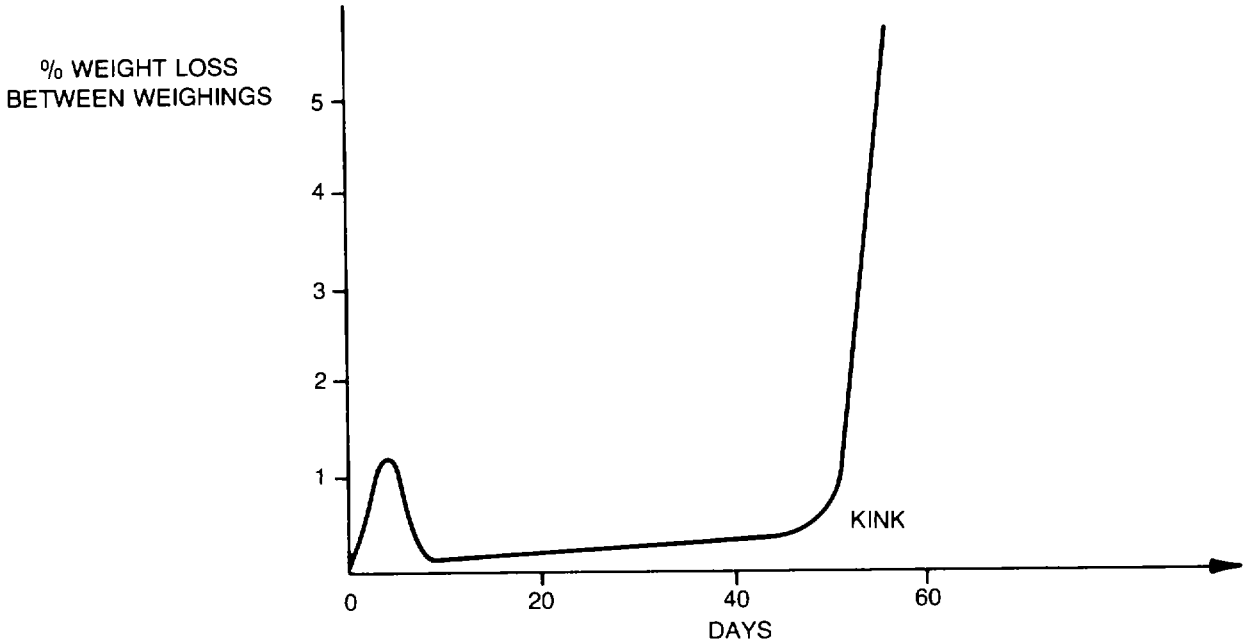


Figure 6-1. 90°C Dutch weight loss test results.

6-20. Shaped Charge Jet Impact. This is a vulnerability test. The propellant is loaded into a standard cartridge. The cartridge is placed behind a 1.27 centimeter (one-half inch) steel plate. A shaped charge jet is fired through the steel plate directly at the cartridge. Video tape and film are used to record the reaction of the propellant in the cartridge. The results are compared to the results for other propellants.

6-21. Shaped Charge Jet Spall. This is a vulnerability test. The propellant is loaded into a standard cartridge. The cartridge is placed behind a 1.27 centimeter (one-half inch) steel plate. A shaped charge is aligned so that the jet does not impact the cartridge shell when fired through the plate, but the spall from the plate does. Video tape and film are used to record the reaction of the propellant in the cartridge.

6-22. Single Fragment Impact. This is a vulnerability test. The propellant is loaded into a standard cartridge. Standard .50 caliber 208 grain fragments are fired into the cartridge at a velocity of about 1,585 meters per second (5,200 feet per second). The velocity of the fragments before impact is recorded and video tape and film are used to record the reaction of the propellant in the cartridge.

6-23. Multiple Fragment Impact. This is a vulnerability test. The propellant is loaded into a standard cartridge. Fragments are explosively launched at a velocity of about 2,286 meters per second (7,500 feet per second) in a pattern such that each cartridge is impacted by at least two fragments. The velocity of the fragments before impact is recorded and video tape and film are used to record the reaction of the propellant in the cartridge.

CHAPTER 7

UNITED STATES PRIMARY EXPLOSIVES

7-1. Introduction. This chapter contains discussions of military primary explosives. The chemical, physical, thermochemical, sensitivity, performance, and stability characteristics of each explosive are covered. The method of manufacture is also given. If known, the chemical structure of each compound is shown. This chapter also contains a discussion of priming compositions.

7-2. Lead Azide.

a. Lead azide, $Pb(N_3)_2$, is a salt of hydrazoic acid, HN3. The compound is white, has a nitrogen content of 28.86 percent and a molecular weight of 291.26. At the melting point, 245°C to 250°C, decomposition into lead and nitrogen gas occurs. The pure compound has two crystal modifications: an orthorhombic form and a monoclinic form. The orthorhombic form, which is also called the alpha form, has a density of 4.68 grams per cubic centimeter and unit cell dimensions of a = 11.31 Angstroms, b = 16.25 Angstroms, and c = 6.63 Angstroms. The monoclinic form, which is also called the beta form, has a density of 4.87 grams per cubic centimeter and unit cell dimensions of a = 18.49 Angstroms, b = 8.84 Angstroms, and c =5.12 Angstroms. The compound is usually prepared as colorless, needlelike crystals. The orthorhombic form is very sensitive. During manufacture, the production of this crystal form must be avoided. Lead azide is soluble in acetic acid and almost insoluble in ether, acetone, alcohol, ammonia, or organic solvents. In water the solubility is 0.02 percent at 18°C and 0.09 percent at 70°C. Lead azide may be dissolved in monoethanolamine or in a 50/50 mixture of monoethanolamine/ammonia. Recovery can be accomplished by adding dilute acetic acid, but the product obtained will be impure. The heat of formation at constant pressure is -112 to -126.3 kilocalories per mole. The calculated heat of detonation is 0.367 kilocalories per gram. Lead azide is used extensively as an ingredient in initiating compositions.

$$[\ N{=}N{=}N\ ]^{-}Pb^{++}[\ N{=}N{=}N\ ]^{-}$$

Figure 7-1. Structural formula for lead azide.

b. The forms of lead azide used for military purposes include the following types. Table 7-1 compares the properties of the types of lead azide.

Table 7-1. Various Types of Lead Azide

Properties	DLA (type I, US)	SLA	CLA (type II, US)	PVA-LA (US)	RD-1333	DCLA
Color	**Buff**	**White**	**White**	**White to buff**		
Lead azide, percent	92.7	98.1	99.9	96.0	98.7	95.3
Total lead, percent	69.3	71.5	71.67	71.6	71.06	69.99
Particle size, mean, microns	24.5	55.0	3.4	19.0	34.5	1.74
Apparent density in grams per cubic centimeter	1.83	-	0.85	-	-	-
Density, pressed at 103,425 kilopascals, (15,000 psi) in grams per cubic centimeter	3.14	3.31	-	3.81	-	-
Sand test values	13.8	-	15.0	-		

Table 7-1. Various Types of Lead Azide (Continued).

Properties	DLA (type I, US)	SLA	CLA (type II, US)	PVA-LA (US)	RD-1333	DCLA
				buff		
Five second explosion temperature	340	350	344	340	345	-
Impact sensitivity Picatinny Arsenal apparatus with 2 kilogram weight, in inches	4-6	2	2-3	4-5	5	3-6
Charge weight in milligrams	28	37	25	30	23	18
Bureau of Mines apparatus with 2 kilogram weight in centimeters	13-28	30	-	13-16	15	-
Picatinny Arsenal apparatus with 500 gram weight in inches	12	-	6	18	15	-
Charge weight in milligrams	28	-	-	31	21	-
Bureau of Mines apparatus with 500 gram weight in centimeters	100 +	-	35	100 +	100 +	-
Minimum charge in milligrams required to initiate 60 milligrams of RDX in an M47 detonator	90	25	-	30	25	-
Vacuum stability in milliliters per gram						
100° C, gas evolved	0.32	-	-	0.20	-	-
120 °C, gas evolved	0.46	-	-	0.44	0.43	-
100°C Heat test:						
Loss in sample wt in 8 hrs, /o	-	0.11	0.12	0.30	-	-
Loss in sample wt in 48 hrs, %	0.34	0.08	-	0.13	0.30	-
Loss in sample wt in 96 hrs, %	0.39	0.16	-	-	0.30	-
Explosion in 100 hrs	None	None	-	None	None	-
Hygroscopicity at room temperature and 90% relative humidity for 56 hours	1.18	0.07	0.02	0.03	-	-

(1) Dextrinated Lead Azide (DLA) is also known as type I lead azide. Dextrin is used as a colloiding agent which prevents the formation of large, sensitive crystals and regulates crystal shape during manufacture.

(2) Service Lead Azide (SLA) consists of lead azide crystals each containing a nucleus of lead carbonate. This form of lead azide is used extensively in the United Kingdom. The method of manufacture of this compound is confidential. SLA is practically nonhygroscopic and is superior to DLA in functioning characteristics. Storage under water is considered hazardous due to the possibility of growth of the crystals and formation of agglomerates which detonate spontaneously. Other long term storage tests dispute this result.

(3) Colloidal Lead Azide (CLA) is also known as type II lead azide. CLA is nondextrinated lead azide of very small particle size. The size of the particles is in the range of three to four microns. CLA is not suited for uses requiring good flow characteristics, but, because of the very fine particle size, is ideal as a spot charge and a priming charge in low energy, electric initiators. CLA successfully replaced the milled DLA formerly used for this purpose, thus eliminating the milling operation which was always considered dangerous, even under carefully controlled conditions. In preparing a spot charge for a low energy, electric detonator, dry CLA is mixed with a concentrated solution of nitrocellulose in ether, alcohol, or other organic solvent, and a small quantity of the resulting paste is placed on the bridgewire to form a droplet called a spot. For a type of detonator in which the bridgewire is located inside a cavity, the charge of CLA can be made in the form of a pellet by pressing wet CLA into the cavity.

(4) Polyvinylalcohol Lead Azide (PVA-LA) consists of lead azide crystals coated with polyvinylalcohol. PVA-LA possesses practically the same sensitivity to impact as DLA, but is much more efficient in detonators and is practically nonhygroscopic. The ignitability is about the same as for straight lead azide and better than for DLA. The normal lead azide content is 93 to 96 percent. Other substances, such as polyethylene glycols and ureaformaldehyde polymer, can be used to produce mixtures with properties very similar to PVA-LA.

(5) RD-1333 lead azide is an insensitive form of lead azide. The method of manufacture as well as some properties of RD-1333 are confidential.

(6) Dextrinated Colloidal Lead Azide (DCLA) is essentially DLA with a very small particle size. The particle size is in the range of one to two microns.

c. In the manufacture of DLA two stock solutions must be prepared. Solution A is prepared by dissolving about 73.9 kilograms (169 pounds) of lead nitrate in about 750 liters of water treated by the permutit demineralization process. Care must be taken to remove all grit and insoluble matter. The pH of this solution is in the range of 4.2 to 4.6. To neutralize this acidity 25 to 30 grams of sodium hydroxide in dilute solution are added. The sodium hydroxide will neutralize the occluded acid and the acid formed by the hydrolysis of the lead nitrate. An excess of sodium nitrate must be avoided to prevent the production of elongated crystals which are very sensitive. About 4.08 kilograms of potato dextrin that was previously dissolved in about 100 liters of water is then added and the solution is brought to 7.325-0.07 percent lead nitrate content. Solution B is prepared by diluting a refined solution of 27 percent sodium azide to 3.175-+0.02 percent sodium azide content. Then 794 grams of sodium hydroxide in the form of pellets are added. The sodium hydroxide is added to neutralize most of the free acid formed during the interaction of solutions A and B. This quantity of sodium hydroxide is also just sufficient to control the purity of the finished lead azide by precipitating a small quantity of lead as $Pb(OH)_2$ or $Pb(OH)N_3$. The solution is then adjusted to 3.175 ± 0.025 percent sodium azide content. Solution A is then heated to between 57.5°C and 60°C with agitation and 50 liters of solution B are added at the rate of two liters per minute. The slow rate of mixing these two very dilute solutions inhibits the formation of the orthorhombic crystalline polymorph. After solution B has been added, the temperature is lowered to 90°C or lower with continued agitation. When agitation stops the lead azide settles out. The precipitate is caught on filter cloths under vacuum and washed with four changes of

water to remove the acidity. To manufacture colloidal lead azide, a solution of four percent sodium azide is maintained at 25°C. Then a solution of lead acetate or lead nitrate is added with agitation. The lead nitrate or acetate is in slight excess of the amount required by the equation:

$$2NaH_3 + Pb(NO_3)_2 \rightarrow Pb(N_3)_2 + 2NaNO_3$$

The resulting slurry is then filtered and the precipitate washed with several changes of water and dried.

d. The specifications for dextrinated lead azide, type I, and collodiol lead azide, type II, are:

Properties	Type I	Type II
Color	White to buff	White to buff
Form, dimension maximum	Free from needle shaped crystal	
Purity, minimum	91.5%	99.0%
Acidity	None	None
Solubility in water, maximum	1.0%	
Particle size geometric mean, micron maximum	-	5
Largest micron maximum	-	10

A needle shaped crystal is defined as a crystal having a length to diameter ratio of 7 to 1 or greater. Needle shaped crystals are more sensitive than crystals of normal shape and tend to detonate under pressure. RD-1333 lead azide must be precipitated from a solution of sodium carboxymethyl cellulose which is used as the crystal growth agent. The color shall be white to buff. The aggregates shall contain no well defined translucent crystals when examined microscopically. The particles shall be opaque and irregular in size and shape and the powder shall be free flowing. RD-1333 lead azide must have a minimum bulk density of 1.1 grams per milliliter, be 98.5 percent pure, have a pH in the range of 7.5 to 5, and have a maximum solubility of one percent in water. In nitric acid, the insoluble material shall be no more than 0.05 percent and none of the material shall be retained on a US standard sieve 230. In addition there shall be no more than trace quantities of iron, copper, chlorides, nitrates, and acetates. Carboxymethyl cellulose may be present in concentrations of 0.6 to 1.20 percent. Another specification for special use lead azide has the same requirements as stated for RD-1333, except there is no limitation for trace quantities of iron, copper, chlorides, nitrates, and acetates.

e. Dextrinated lead azide is less sensitive to impact than mercury fulminate, lead styphnate, diazodinitrophenol, tetracene, or crystalline lead azide. The small aggregates that pass through a No. 325 sieve are slightly less sensitive than those that pass through a No. 230 sieve and are retained on a No. 270 sieve. When wet with water or 95 percent ethanol, lead azide has the comparative sensitivity values shown by table 7-2. The impact test results are from the Picatinny Arsenal apparatus with a two kilogram weight.

Table 7-2. Sensitivity of Dry and Wet Lead Azide

Composition, percent			Impact	Pendulum friction test			
				Fiber shoe		Steel shoe	
Lead azide	Water	Ethanol	test inches	Trials	Detonation	Trials	Detonation
100	-	-	4	1	1	-	-
80	20	-	9	10	0	4	1
80	-	20	4	1	1	-	-
75	25	-	9	10	0	12	0

The five second explosion temperature is 315°C to 345°C for pure lead azide and 275°C for dextrinated lead azide. These temperatures are much greater than the corresponding values for mercury fulminate, lead styphnate, diazodinitrophenol, and tetracene and reflect the greater difficulty in igniting lead azide in practical use. The maximum static discharge for which no ignition takes place is 0.01 joules.

f. When subjected to the sand test, dextrinated lead azide is 95 percent as brisant as the pure crystalline material and 40 percent as brisant as TNT. At maximum density, the rate of detonation is 5,400 meters per second. The rate of detonation for samples with densities of 3.8 and 4.6 grams per cubic centimeter are 4,500 and 5,300 meters per second, respectively. Slightly higher values than these have been reported. The temperature developed on detonation is between 3,420°C and 3,484°C and the pressure developed on detonation is 94,930 kilograms per square centimeter. When lead azide detonates, 308 milliliters of gas are evolved per gram of explosive with the lead produced in the gaseous form. Trauzl lead block tests have shown dextrinated lead azide to be 89 percent as powerful as the pure compound but only 80 percent as powerful as mercury fulminate and 40 percent as powerful as TNT.

g. Lead azide is an excellent initiating agent for high explosives. While not superior to mercury fulminate for detonating the less sensitive explosives such as TNT, lead azide is markedly superior as an initiator for the more sensitive explosives such as tetryl, RDX, and PETN. Unlike diazodinitrophenol, lead azide cannot initiate the detonation of ammonium picrate or cast TNT.

h. The stability of dextrinated as well as pure lead azide is exceptional. This is indicated by 100°C heat and vacuum stability tests and also by storage tests. No change is found with respect to purity or brisance after storage for 25 months at 50°C or under a water-ethanol mixture at ordinary temperature. Storage at 80°C for 15 months caused no decrease in brisance and, after such storage, a priming composition containing lead azide showed no decrease in sensitivity to stab action. The beta form is considerably less stable than the alpha form and undergoes decomposition much more rapidly. Low X-ray dosages cause lead azide crystals to decrepitate with heat and increase in hardness. Higher X-ray dosage produces severe damage. Ninety-eight percent destruction of an SLA sample was observed after an X-ray dose of 3.5 x 108 rontgen. Lead azide corrodes copper with the formation of cupric azide. Cupric azide is highly sensitive, so tools of brass, bronze, or copper cannot be used with lead azide. Figure 7-2 shows the DTA curve for lead azide.

7-3. Mercury Fulminate.

a. Mercury fulminate, $Hg(ONC)_2$, is a salt of fulminic or paracyanic acid. The acid undergoes polymerization very rapidly in both aqueous and ethereal solutions, and so cannot be isolated. The structure of fulminic acid, and thus the salts of this acid, is undetermined. Mercury fulminate has an oxygen balance to CO_2 of-17 percent, an oxygen balance to CO of -5.5 percent, a nitrogen content of 9.85 percent, and a molecular weight of 284.65. When mercury fulminate is crystallized from water, a hydrate, Hg(ON: C).1/2 H_20, is formed that has a nitrogen content of 9.55 percent and a molecular weight of 293.64. The anhydrous form, which is crystallized from alcohol, is white when pure but normal manufacturing yields a gray product of only 98 to 99 percent purity. The crystals formed are octahedral but are usually truncated. Only the smaller crystals are fully developed. The crystal density is 4.43 grams per cubic centimeter. Table 7-3 shows the density of mercury fulminate as a function of loading pressure.

Table 7-3. Loading Density of Mercury Fulminate

Pressure in kilopascals	Pressure in pounds per square inch	Density in grams per cubic centimeter
20,685	3,000	3.0
68,450	10,000	3.6
137,900	20,000	4.0
344,750	50,000	4.3

Pressures of more than 172,375 to 206,850 kilopascals (25,000 to 30,000 pounds per square inch) cause mercury fulminate to be desensitized to the extent of becoming dead pressed. Such material merely ignites and burns when subjected to contact with flame. The dead pressed material can be detonated by a strong blasting cap. If a layer of loose or only slightly pressed mercury fulminate covers the dead pressed material, the ensemble can be detonated by ignition. When the dead pressed material is detonated, the velocity of detonation is greater than for material that has not been dead pressed. Mercury fulminate has a melting point of 160°C, but explodes at that temperature. The solubility in one liter of water is 0.71 grams at 12°C, 1.74 grams at 49°C, and 7.7 grams at 100°C. The solubility in ethanol is slight. Because of these slight solubilities, mercury fulminate can be stored underwater or, if there is danger of freezing, under a mixture of equal volumes of water and ethanol or methanol. After such storage the compound can be dried easily. Aqueous ammonium

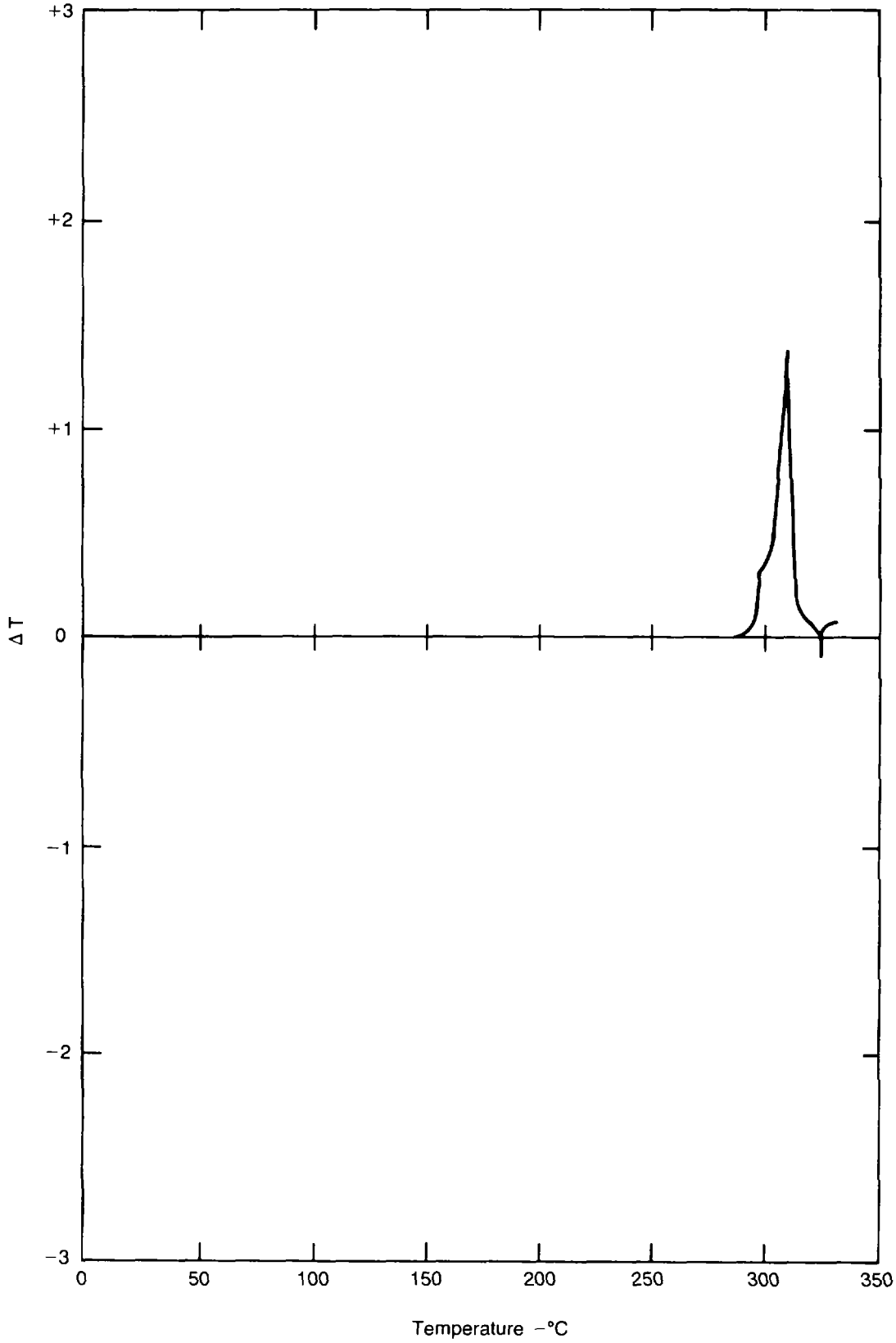


Figure 7-2. DTA curve for lead azide.

hydroxide, aqueous potassium cyanide, and pyridine dissolve mercury fulminate. The compound can be recovered by treating the ammonium or potassium solution with acid and the pyridine solution with water. The heat of formation is 221 to 226 calories per gram, heat of combustion is 938 calories per gram, and the heat of explosion is 427 calories per gram. Mercury fulminate was used extensively as an initiator, however, poor stability has prompted replacement of this compound by such initiators as lead azide.

b. Mercury fulminate reacts with concentrated hydrochloric acid to produce hydroxylamine, H_2N,OH, and formic acid, HCOOH. The reaction with sodium thiosulfate in aqueous solution forms mercury tetrathionate according to the equation:

$$Hg(ONC)_2 + 2Na_2\ S_203 + H_20 \rightarrow$$
$$HgS_4O_6 + 2NaOH + NaCN + NaNCO$$

If allowed to stand, a secondary reaction occurs with the formation of sulfate and thiocyanate according to the equation:

$$HgS_4O_6 + 2NaOH + NaCN + NaNCO \rightarrow$$
$$HgSO_4 + Na_2SO_4 + 2NaNCS + H_2O$$

The first reaction can be used for the determination of the purity of mercury fulminate. Even in the presence of 0.5 percent moisture, pure mercury fulminate does not react with any of the common metals. However, the standard grade of the compound may contain as much as one percent free mercury, formed by exposure to light or elevated temperatures. The free mercury readily forms amalgams with copper, brass, or bronze, so components containing these metals must be protectively coated if used with mercury fulminate.

c. Mercury fulminate is manufactured in relatively small quantities. About one pound of redistilled mercury is added to an open, earthenware vessel or five liter flask that contains eight to ten pounds of nitric acid with a specific gravity of 1.4. The nitric acid is in excess of the amount required by the equation:

$$3Hg + 8HN0_3 \rightarrow 3Hg(NO_3)_2 + 2NO + 4H_20$$

A large number of such charges are usually prepared and allowed to stand overnight until the mercury is completely dissolved. The charges are then poured into a large balloon flask which contains eight to ten pounds of 95 percent ethanol. The flask rests in a bath of running, cold water. This installation has to be either outside or in a building provided with an exhaust system. The flask is fitted with a reflux condenser. About two to three minutes after the acidic solution of mercury nitrate is added to the ethanol, a violent reaction starts and the liquid boils with the evolution of white fumes. Most of these fumes are recovered by the condenser. As the reaction approaches the end point, the fumes change color to brownish-red because of the decomposition of nitric acid by heat. A small quantity of dilute alcohol is added at this point to moderate the reaction and prevent the decomposition of the mercury fulminate by the heat of reaction. The reaction normally takes about an hour and a half. The reaction mix is then allowed to cool to room temperature, at which time all the mercury fulminate has settled out. The mercury fulminate crystals are then caught on a screen and washed with cold water until free of acid and five impurities known as fulminate mud. The washed mercury fulminate is then drained and packed into cloth bags which are stored in tanks of water until required for use. The acid mother liquor and the water washings are neutralized with alkali, evaporated to recover the alcohol, and treated to recover any mercury or mercury salts. The yield of the process is 120 to 130 parts per 100 parts of mercury.

d. In the manufacturing process ethyl nitrate ($C_2H_5.ONO_2$), ethyl nitrite ($C_2H_5.ONO$), and nitroethane ($C_2H_5NO_2$) also are produced. The intermediate products of oxidation and nitration involved in the preparation of mercury fulminate are as follows:

$CH_3.CH_2OH \rightarrow$ Ethanol

$CH_3.CHO \rightarrow$ Acetaldehyde

$CH_2(NO).CHC \rightarrow$ Nitrosoacetaldehyde

$CH(:NOH).CHO \rightarrow$ Isonitrosoacetaldehyde

$CH(:NOH).COOH \rightarrow$ Isonitrosoacetic acid

$C(NO_2)(:NOH).COOH \rightarrow$ Nitroisonitrosoacetic acid

$O_2H.CH:NOH \rightarrow$ Formonitrolic acid

$C:NOH \rightarrow$ Fulminic acid

$Hg(ONC)_2$ Mercury fulminate

The product so obtained is not more than 99 percent pure. The material can be purified so as to have a fulminate content of 99.75 percent or more by dissolving the impure material in concentrated ammonium hydroxide, filtering the solution, cooling the filtrate, and reprecipitating slowly adding concentrated nitric acid with rapid agitation while keeping the temperature below 35°C. Conditions can be established so that the

precipitated fulminate is of essentially the same granulation as the impure material. The precipitated pure fulminate is washed with distilled water until free of acid. The yield is 80 to 87 percent.

e. Mercury fulminate for military use consists of one grade. The requirements applying are:

Appearance:	Crystals of sparkling appearance that are white, gray, or light gray with a yellowish tint.
Granulation:	A maximum of 15 percent retained on a No. 100 and a maximum of 75 percent passing through a No. 200 sieve.
Sand test:	0.400 gram shall crush a minimum of 44 grams of sand.
Mercury fulminate:	Minimum, 98.0 percent.
Acidity:	None.
Insoluble matter:	Maximum, 2.0 percent.
Free mercury:	Maximum, 1.0 percent.
Chlorine:	Maximum, 0.05 percent.

The chlorine content requirement is due to the occasional use of a small quantity of cupric chloride, $CuCl_2$, for the purpose of improving the color of the product. The chloride is added to the solution of mercury in nitric acid. While this improves the color, there is also a decrease in the purity of the product. The insoluble matter represents decomposition products, which are formed as the result of side reactions.

f. The impact sensitivity on the Bureau of Mines apparatus with a 20 milligram sample is five millimeters and on the Picatinny Arsenal apparatus with a nonstandard 2.2 kilogram weight is four inches. This indicates mercury fulminate is more sensitive to impact than lead azide and lead styphnate. Being of the same sensitivity to impact as diazodinitrophenol and tetracene, these three compounds are the most sensitive initiating explosives used in military ammunition. Mercury fulminate is more sensitive to friction than lead azide and lead styphnate, exploding with both the steel and fiber shoe. The five second explosion temperature is 210°C which indicates mercury fulminate is more sensitive to heat than lead azide or lead styphnate, but less sensitive than diazodinitrophenol and tetracene. The sensitivity of mercury fulminate to percussion is one of the compound's most advantageous characteristics. Mercury fulminate is highly sensitive to electric spark. A spark from a person charged to less than 5,000 volts causes ignition. This condition is possible in plant operations. The sensitivity to electrostatic discharge is reported to be 0.025 to 0.07 joules.

g. The sand test indicates mercury fulminate is 27.3 to 59 percent as brisant as TNT. The rate of detonation of a charge with a density of 2.0, 3.0, and 4.0 grams per cubic centimeter is 3,500, 4,200, and 5,000 meters per second. When ignited, a single crystal will burn rapidly with a flash, but detonation does not take place. When a layer of crystals is ignited, high order detonation takes place. The Trauzl test indicates a power of 37 to 50 percent of TNT. Mercury fulminate is distinctly more powerful than lead azide.

h. Although mercury fulminate is not as efficient an initiator of detonation as lead azide and diazodinitrophenol, satisfactory results are obtained when used in conjunction with tetryl, RDX, or PETN, the most generally used booster explosives. The number of grams of mercury fulminate required for complete detonation of TNT is 0.25 to 0.36, for tetryl is 0.20 to 0.29, for RDX is 0.19, for PETN is 0.17, and for explosive D is 0.85.

i. Mercury fulminate is no longer used by the United States military because of poor stability. The usual stability tests are not applicable to mercury fulminate, due to explosion in a relatively short time at temperatures above 85°C. The products of deterioration are nonexplosive solids rather than gases. When the purity of mercury fulminate is reduced to about 92 percent, the initiating efficiency is destroyed although the material will explode when ignited. When purity has been reduced to 95 percent, the stability of mercury fulminate must be considered seriously impaired. Table 7-4 gives a summary of the approximate times of storage required to cause deterioration to 92 percent and 95 percent. Mercury fulminate gains 0.02 percent when exposed to 90 percent relative humidity at 30°C. When dry, mercury fulminate reacts rapidly with aluminum and magnesium and reacts slowly with copper, zinc, brass, and bronze. When wet, mercury fulminate reacts immediately with aluminum and magnesium and rapidly with copper, zinc, brass, or bronze. Dry or wet, the compound does not effect iron or steel.

Table 7-4. Deterioration of Mercury Fulminate

Storage temperature °c	Time required to reduce purity to					
	95 percent			92 percent		
	Days	Months	Years	Days	Months	Years
80	0.5	-	-	1	-	-
50	-	8	-	-	11	-
30-35	-	-	1.7	-	-	5.8
20	-	-	7	-	-	9
10	-	-	8	-	-	10

7-4. Diazodinitrophenol (DDNP).

a. This explosive is also known as 4,5-dinitrobenzene-2-diazo-1-oxide, dinol, diazol and may be referred to as DADNP. The compound (figure 7-3) is a greenish yellow to brown solid with tabular crystals. DDNP has a crystal density of 1.63 to 1.65 grams per cubic centimeter at 25°C and a molecular weight of 210.108. DDNP is not dead pressed even at a pressure of 896,350 kilopascals (130,000 pounds per square inch). The solubility of DDNP in various solvents is shown in table 7-5.

Table 7-5. Solubility of Diazodinitrophenol

	Solubility, grams per 100 grams of solvent at-	
	25°C	50°C
Water	0.08	-
Benzene	0.09	0.23
Methanol	0.57	1.25
Ethanol	0.84	2.43
Ether	0.04	-
Chloroform	-	0.11
Ethylene chloride	0.29	-
Acetic acid	1.40	-
Ethyl acetate	-	2.45
Acetone	6.0	-

DDNP is also soluble to some extent in nitroglycerin, nitrobenzene, aniline, pyridine, and concentrated hydrochloric acid. DDNP is nearly insoluble in carbon tetrachloride and carbon disulfide. The heat of formation is 956 calories per gram and the heat of explosion is 820 calories per gram. DDNP is used as an ingredient in priming compositions and in commercial blasting caps.

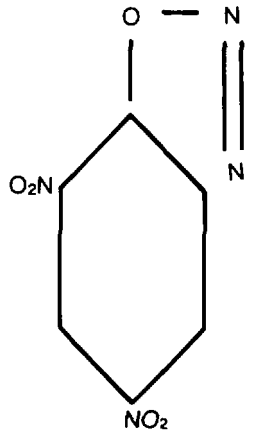


Figure 7-3. Structural formula for DDNP.

b. At ordinary temperatures DDNP does not react with water, but the mixture of the two is less sensitive than DDNP alone. DDNP is darkened rapidly by exposure to sunlight, probably because of oxidation at the surface.

c. The process used commercially for the manufacture of DDNP is not available, but the compound can be prepared by the diazotization of picramic acid by means of sodium nitrite and hydrochloric acid. The reactions involved are shown in figure 7-4. Picramic acid may be prepared by evaporating a mixture of an alcoholic solution of ammonium picrate and ammonium sulfide and purifying the product. Ten grams of picramic acid are suspended in 120 milliliters of a five percent aqueous solution of hydrochloric acid. The mixture is cooled with an ice bath and stirred rapidly. A solution of 3.6 grams of sodium nitrite in 10 milliliters of water is added all at once and stirring is continued for 20 minutes. The dark brown, granular material that separates

is caught on a filter and washed with ice water until the washings give no indication of hydrochloric acid or sodium chloride. If this material is dissolved in hot acetone and a large volume of ice water added to the agitated solution, the DDNP is precipitated as a bright yellow, amorphous powder. Recrystallization from a solvent is used to produce the tabular crystals that comprise specification grade material. After manufacture, the DDNP is kept wet with water until used.

d. Only one grade of DDNP is used for military purposes. This complies with the following requirements:

Color:	Greenish yellow to brown.
Form:	Tabular crystals having a maximum length of 0.2 millimeter.
Granulation:	100 percent shall pass through a No. 100 US standard sieve.
Bulk density:	Minimum, 0.4 grams per milliliter.
Acidity:	Maximum, 0.01 percent as hydrochloric acid.
Sand test:	0.40 gram shall crush not less than 33 grams of sand.

e. DDNP is less sensitive to impact than lead azide or mercury fulminate. The friction sensitivity is approximately the same as lead azide but less than mercury fulminate. The five second explosion temperature is 195°C. A mixture of DDNP and water is desensitized to the extent that a number eight blasting cap cannot cause detonation. DDNP detonates when struck with a sharp blow. An unconfined sample burns with a flash if ignited but even the slightest confinement causes a transition from burning to detonation. A charge of DDNP undergoes detonation when ignited if pressed into a blasting cap shell with a reinforcing cap and a piece of black powder safety fuse crimped in the shell. A spark falling into the open end of such a blasting cap causes only ignition and flashing of the DDNP. The maximum energy of a static discharge that does not cause ignition is 0.25 joules.

f. The sand test indicates DDNP is 94 to 105 percent as brisant as TNT. DDNP is considerably more brisant than mercury fulminate, lead azide, lead styphnate, and tetrazene. At a density of 1.58 grams per cubic centimeter DDNP and TNT have the same velocity of detonation, 6,900 meters per second. At densities of 0.9 and 1.63 grams per cubic centimeter the detonation velocities are 4,100 and 7,100 meters per second, respectively. The Trauzl test and ballistic mortar test indicate that DDNP is 110 percent and 95 percent as powerful as TNT, respectively. The gas volume produced on detonation is 856 liters per kilograms.

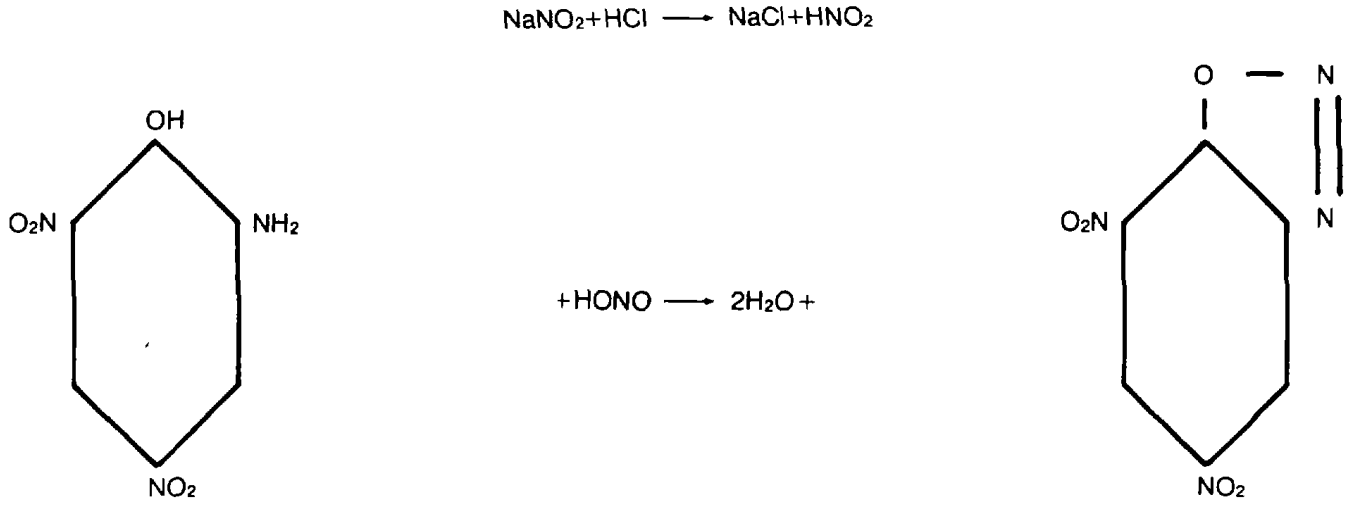


Figure 7-4. Preparation of DDNP.

g. The sand test indicates DDNP is a better initiator of detonation than mercury fulminate or lead azide for less sensitive high explosives. The most marked evidence of this is the ability of DDNP to initiate the detonation of ammonium picate and cast TNT. For initiation of the more sensitive high explosives, DDNP is not superior to lead azide. Comparative values showing relative initiating efficiencies are given in table 7-6.

Table 7-6. Efficiency of Initiating Compounds

	Minimum detonating charge, gram of initiator required to detonate		
	Tetryl	**TNT**	**Ammonium picrate**
Lead azide	0.10	0.26	No detonation
Mercury fulminate	0.19	0.24	No detonation
Diazodinitrophenol	0.12	0.15	0.28

h. In the vacuum stability test at 100°C, 7.6 cubic centimeters of gas are evolved from a five gram sample in 40 hours. In the 100°C heat test, 2.10 percent is lost in the first 48 hours, 2.20 percent in the second 48 hours, and no explosions occur in 100 hours. These results indicate DDNP is not as stabile as lead azide, but is markedly more stabile than mercury fulminate. Storage tests have shown dry DDNP to withstand storage at 50°C for at least 30 months, as compared with nine months for mercury fulminate. When stored under water, DDNP is of unimpaired brisance for 24 months at ordinary temperature and for 12 months at 50°C. The stability of DDNP, therefore, is considered satisfactory for commercial and military use, and DDNP and lead azide have replaced mercury fulminate in blasting caps to a large extent. DDNP is hygroscopic to the extent of 0.04 percent in an atmosphere of 90 percent relative humidity at 30°C.

7-5. Lead Styphnate.

a. Two forms of lead styphnate are used as primary explosives: basic (figure 7-5) and normal (figure 7-6). Basic lead styphnate has a nitrogen content of six percent and a molecular weight of 705.53. The compound has two crystal forms: yellow needles with a density of 3.878 grams per cubic centimeter and red prisms with a density of 4.059 grams per cubic centimeter. The apparent density is 1.4 to 1.6 grams per cubic centimeter. Normal lead styphnate has a nitrogen content of nine percent and the monohydrate has a molecular weight of 468.38. The compound has yellow orange or reddish brown, rhombic, needle like crystals with a density of 3.02 grams per cubic centimeter at 30°C. The anhydrous salt has a density of 2.9 grams per cubic centimeter. Both forms of lead styphnate are soluble in aqueous ammonium acetate. Basic lead styphnate is practically insoluble in water; normal lead styphnate is only soluble to the extent of 0.04 percent at room temperature. Normal lead styphnate is even less soluble in methanol and ethanol than in water. Both forms of lead styphnate are insoluble in ether, chloroform, carbon tetrachloride, carbon disulfide, benzene, toluene, concentrated hydrochloric acid, and glacial acetic acid. Normal lead styphnate has a heat of formation of 92.3 calories per gram, a heat of combustion of 1,251 calories per gram, and a heat of detonation of 460 calories per gram. Both forms of lead styphnate are used as ingredients in priming compositions. When used alone, despite a favorable rate of detonation and good power characteristics, lead styphnate is a relatively poor initiator of detonation. Detonation of 60 percent dynamite and sometimes gelatin dynamite is possible. However, of the military high explosives, only unpressed PETN can be detonated. The minimum detonating charge for unpressed PETN is 0.55 gram, as compared to 0.30 gram of mercury fulminate or 0.40 gram of lead azide. The ease of ignition of the compound has led not only to use in priming compositions, but also use as a cover charge for igniting lead azide.

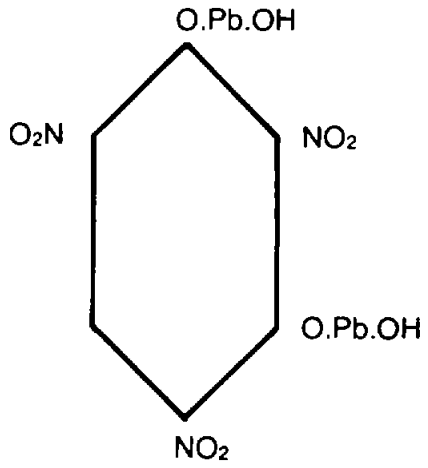


Figure 7-5. Basic lead styphnate.

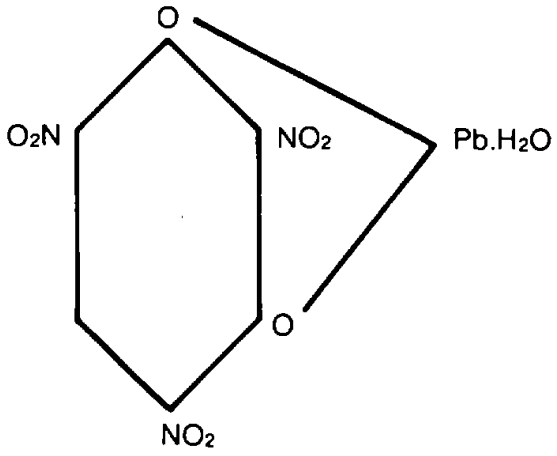


Figure 7-6. Normal lead styphnate.

b. Lead styphnate can be prepared by the reaction of lead nitrate or acetate with either sodium or magnesium styphnate in the presence of an acid. In commercial production, the magnesium salt is used. This is prepared by the reaction of magnesium oxide and styphnic acid (2,4,6-trinitroresorcinol). In one procedure, a boiling solution of lead nitrate is added to a boiling solution of sodium styphnate acidified with acetic acid. In another procedure, solutions of magnesium styphnate and lead acetate are caused to react at 70°C to form a precipitate of basic lead styphnate, which is converted into the normal salt by the addition of dilute nitric acid. The insoluble product is filtered off and washed with water until free of acid. Like other initial detonating compounds, lead styphnate is kept under water or under a water-isopropyl alcohol mixture until used.

c. For military use basic lead styphnate must comply with the following requirements:

Appearance:	The material shall be free from visible impurities and aggregates of crystals. Type I shall be yellow to orange yellow in color. Type II shall be yellow brown to brown in color.
Crystal form:	Type I material shall consist of discrete crystals in the form of needles. Type II material shall consist of discrete crystals.
Crystal dimensions:	95 percent of the type I crystals shall have a maximum dimension between 7 and 20 microns. The length of the crystal shall not be greater than five times the width of the crystal. 95 percent of the type II crystals shall have lengths between 7 and 35 microns.
Granulation:	100 percent of the type I and II material shall pass through a US standard number 325 sieve.
Apparent density:	The apparent density of the type I material shall be 0.3 to 0.5 grams per milliliter and for the type II material, 1.40 to 1.60 grams per milliliter.
Acidity:	The pH shall be 5.0 to 6.0 in a one percent solution for the type I material, 6.0 to 7.0 for the type II material.
Material insoluble in ammonium acetate:	0.2 percent, maximum, for both type I and II material.
Material soluble in ether:	0.1 percent, maximum, for both type I and II material.
Lead content:	59.6 to 60.2 percent for both type I and II material.
Nitrogen content:	5.97 to 6.17 percent for both type I and II material.
Instantaneous flash point:	330°C to 350°C for both type I and II material.

d. For military use normal lead styphnate must comply with the following requirements:

Appearance:	The material shall be free from visible impurities and aggregates of crystals and be yellow brown to brown in color.
Crystal form:	The material shall consist of the discrete crystals of the monoclinic system and the longest dimension of any crystal shall not be greater than three times the next longest axis. Hexagonal plates are acceptable.
Crystal dimension:	The largest dimension of any crystal shall not exceed 0.5 millimeter.
Granulation:	100 percent of the material shall pass through a US standard number 100 sieve.
Apparent density:	1.30 to 1.60 grams per cubic centimeter.
Acidity:	The pH shall be between 5.0 and 6.0 in a one percent solution.
Material insoluble in ammonium acetate:	0.3 percent, maximum
Material soluble in ether:	0.1 percent, maximum
Lead content:	43.2 to 44.3 percent
Nitrogen content:	8.87 to 9.07 percent
Instantaneous flash point:	310°C to 330°C

e. Normal lead styphnate is slightly less sensitive to impact than mercury fulminate or diazodinitrophenol, but is more sensitive than lead azide. The friction sensitivity is less than that for mercury fulminate or lead azide. The five second explosion temperature is 282°C, less than that for lead azide but much greater than those of mercury fulminate and diazodinitrophenol. Normal lead styphnate is much more easily ignited by flame or electric spark than mercury fulminate, lead azide, and diazodinitrophenol. The sensitivity to electrostatic static discharge is 0.001 joules. When ignited, the rate of detonation is less than the maximum rate. The calculated activation energy for the decomposition of lead styphnate is 61.5 kilogram-calories per gram molecule as compared with a value to 25.2 kilogram-calories for mercury fulminate.

f. When subjected to the sand test with ignition by a black powder fuse, the brisance of normal lead styphnate (10.5 grams of sand crushed) is much less than that of lead azide (16.7 grams of sand crushed). However, when initiated with a small charge of mercury fulminate or lead azide, the brisance (24 grams of sand crushed) is greater than that of lead azide or mercury fulminate. The range of brisance reported is from 27 to 53 percent of TNT. When initiated with blasting caps, lead styphnate pressed to a density of 2.9 has a rate of detonation of 5,200 meters per second, which is greater than the rate of detonation of either lead azide or mercury fulminate at the same density. Trauzl lead block tests, with large and small blocks, show lead styphnate to be more powerful than lead azide and 42 percent as powerful as TNT.

g. Normal lead styphnate is of a high order of stability as indicated by vacuum stability tests at 100°C and 120°C. In both tests 0.4 cubic centimeters of gas are evolved in 40 hours. The loss of 1.5 percent in the 100°C heat test may be attributable to the removal of the water of crystallization, which is present to the extent of 3.84 percent. Storage at 80°C caused no change in the 120°C vacuum stability test value, although the explosion temperature and sand test values were increased slightly. These changes also may be attributable to loss of the water of crystallization. The stability of lead styphnate is the same as lead azide and better than that of mercury fulminate or diazodinitrophenol. Figure 7-7 shows the DTA curve for lead styphnate and figure 7-8 shows the TGA curve.

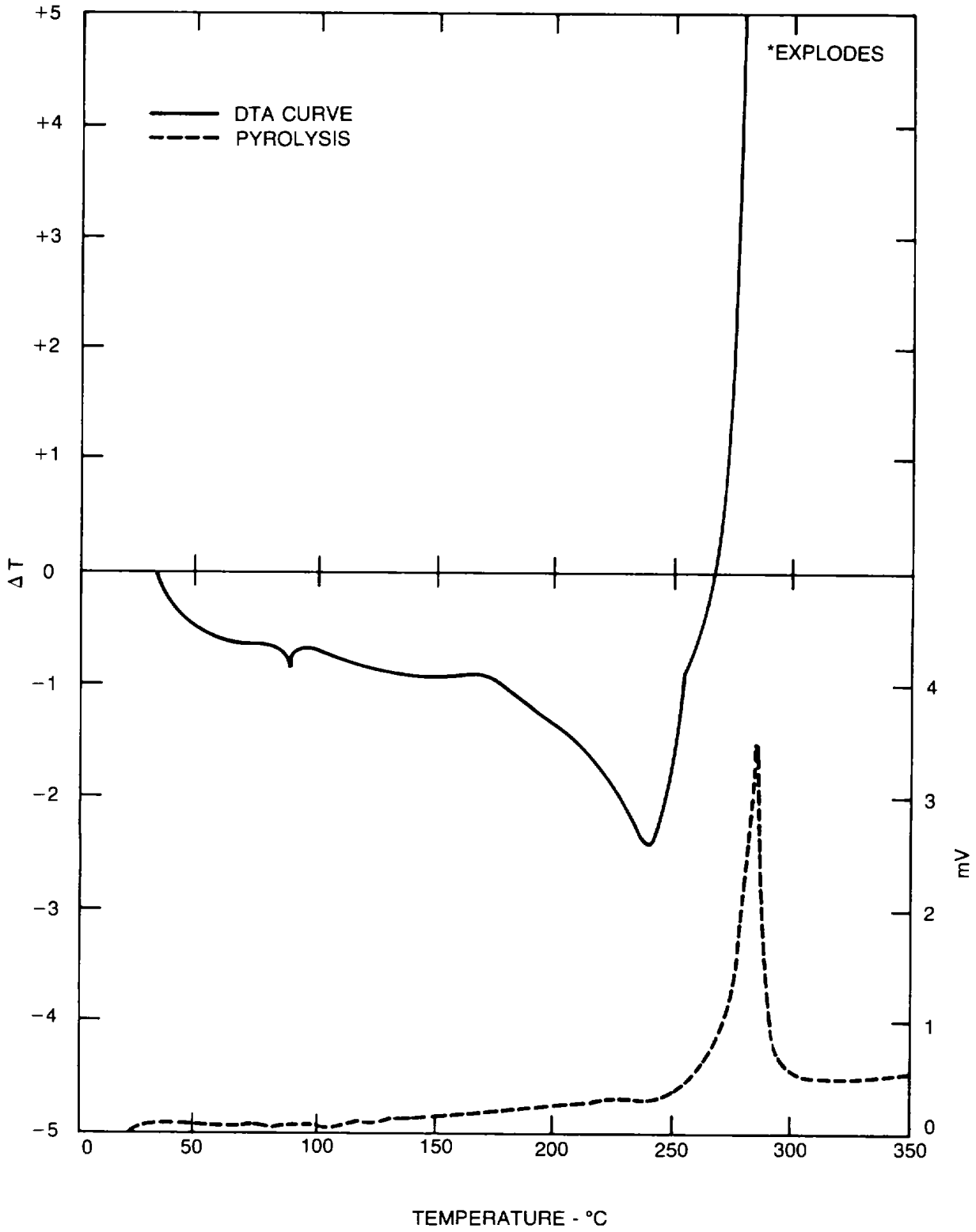


Figure 7-7. DTA curve for lead styphnate.

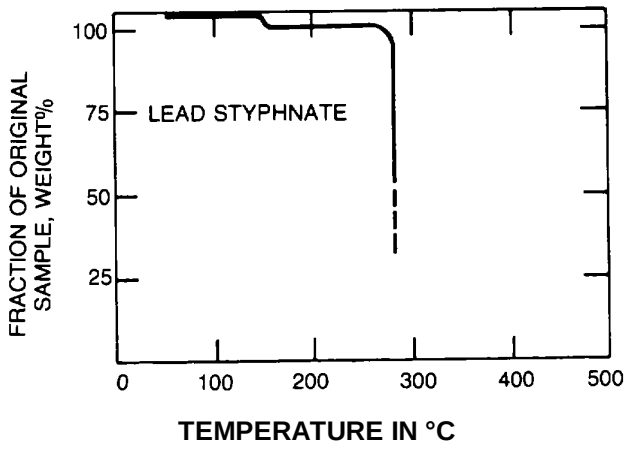


Figure 7-8. TGA curve for lead styphnate.

7-6. Tetracene.

a. Tetracene is also known as guanyldiazoguanyl tetrazene and 4-guanyl-1 -(nitrosoaminoguanyl)-1 tetrazene. The compound (figure 7-9) is a colorless to pale yellow, fluffy material with needle crystals, an oxygen balance to CO_2 of-57.6 percent, an oxygen balance to CO of-43 percent, a nitrogen content of 74.4 percent, and a molecular weight of 188.15. Tetracene forms a hydrate with three molecules of water. The melting point of the pure compound is between 140°C and 160°C accompanied by decomposition and explosion. The apparent density is only 0.45 grams per cubic centimeter. When compressed at 20,685 kilopascals (3,000 pounds per square inch), the density is 1.05 grams per cubic centimeter. The crystal density is 1.7 grams per cubic centimeter. The compound can be easily dead pressed. Tetracene is practically insoluble in water and ethanol and so can be stored wet with water or a mixture of water and ethanol. The compound is also insoluble in ether, benzene, acetone, carbon tetrachloride, and ethylene dichloride. Tetracene is soluble in dilute nitric acid or strong hydrochloric acid. In a solution with hydrochloric acid, the hydrochloride is precipitated by the addition of ether. Tetracene may then be recovered by treatment with sodium acetate or ammonium hydroxide. The heat of formation is 270 calories per gram and the heat of detonation is 658 calories per gram. Tetracene can be used in detonators when initiated by another primary explosive. In such cases, the tetracene functions as an intermediate booster or as a sensitizer to flame or heat. In some cases, tetracene is used in primers where as little as two percent tetracene in the composition results in uniformity of percussion sensitivity.

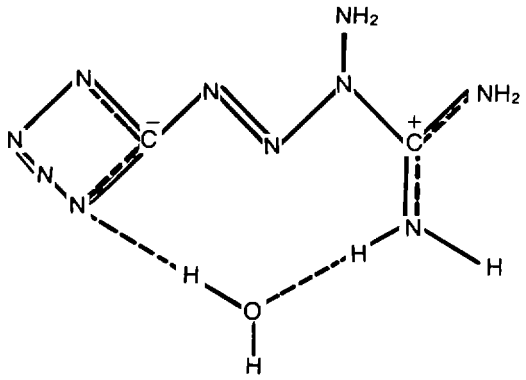


Figure 7-9. Structural formula for tetracene.

b. Boiling water decomposes tetracene liberating two molecules of nitrogen per molecule of tetracene. Hydrolysis with sodium hydroxide yields ammonia, cyanamide, and triazonitrosoaminoguanidine (N3C(:NH).NH.NH.NO). Tetracene reacts with an excess of silver nitrate to form the double salt $C_2H_7N_{10}OAg.AgNO_3.3H_2O$ and forms explosive salts such as the perchlorate.

c. To prepare tetracene, 34 grams of aminoguanidine carbonate are dissolved, with warming, in a mixture of 2.5 liters of water and 15.7 grams of glacial acetic acid. After the solution has been filtered and cooled to 30°C, 27.6 grams of solid sodium nitrite are added. The sodium nitrite is dissolved by stirring. After standing for three or four hours, the solution is shaken to start precipitation and the mixture is allowed to stand for about 20 hours longer. The precipitate of tetracene is separated and washed with water until free from acid. An alternate method is to dissolve five grams of aminoguanidine dinitrate in 30 milliliters of distilled water, cooling to 0°C, and mixing with a solution

of 2.5 grams of sodium nitrite in 15 milliliters of water. While maintaining the temperature at 10°C, 0.5 grams of glacial acetic acid is added to precipitate the tetracene. After allowing the slurry to stand, at least overnight, the precipitate is washed by decantation with several portions of water and then transferred to a filter to be washed more thoroughly with water using suction. Then the product is air dried at room temperature. Another method for the preparation of tetracene uses aminoguanidine sulfate and sodium nitrite in distilled water.

d. Tetracene must meet the following requirements for military use:

Color and appearance:	Tetracene shall be white to light yellow and under the microscope shall appear as needle shaped crystals.
Melting and explosion point:	130±2°C.
Granulation:	100 percent shall pass through a US number 45 standard sieve.
Specific gravity:	1.65±0.05.
Heavy metals:	There shall be no heavy metals present.
Nitrogen content:	74.5+1 percent.

e. Tetracene is of the same order of sensitivity as mercury fulminate and diazodinitrophenol. Using the Bureau of Mines apparatus with a two kilogram weight, the result obtained is seven centimeters as compared to five centimeters for mercury fulminate. Using the Picatinny Arsenal apparatus with a 226.8 gram (eight ounce) weight, the result obtained is eight inches, as compared to nine to ten inches for mercury fulminate. The five second explosion temperature (160°C) is relatively low as compared with the other initial detonating agents. This ease of ignition along with a relatively high heat of explosion and large gas volume produced makes tetracene useful in priming compositions and with lead azide in explosive rivets. When exposed to contact with a flame, tetracene undergoes mild explosion with the production of much black smoke. The minimum detonating charge of mercury fulminate is 0.40 grams.

f. In the sand test, loose tetracene crushes 13.1 grams of sand, but when loaded under a pressure of 20,685 kilopascals (3,000 pounds per square inch), only two grams of sand are crushed. However, tetracene pressed at 20,685 kilopascals crushes 21.1 grams of sand when initiated with mercury fulminate. This maximum brisance is equal to that of mercury fulminate. The range of brisance values reported are 40 percent to 70 percent of TNT. The volume of gas developed on explosion is 1,190 cubic centimeters per gram. The Trauzl test indicates tetracene has a power of 51 to 63 percent of TNT.

g. Unpressed tetracene, when ignited by a flame, can cause the detonation of loose or pressed PETN, but pressed tetracene does not detonate PETN. Unpressed tetracene can cause low order detonation of tetryl. The unpressed material, however, cannot detonate TNT even when primed with mercury fulminate. Tetracene, therefore, does not have sufficient initiating efficiency to be used with military high explosives.

h. Tetracene is relatively stable at temperatures not greater than 75°C. However, in the 100°C heat test, extreme decomposition occurs in the first 48 hours. The reactivity with water and the slightly high 75°C international test value (0.5 percent) indicate an order of stability approximating that of mercury fulminate. Tetracene gains only 0.77 percent in an atmosphere with 90 percent relative humidity at 30°C.

7-7. Potassium Dinitrobenzofuroxane (KDNBF).

a. KDNBF (figure 7-10) is a red crystalline solid with a nitrogen content of 21.21 percent and molecular weight of 264.20. The oxygen balance of the compound to CO_2, H_2O, and K_2O is -42.4 percent. The anhydrous salt has a density of 2.21 grams per cubic centimeter and a melting point, with explosive decomposition, of 210°C. KDNBF is soluble to the extent of 0.245 grams per 100 grams of water at 30°C. Between the temperatures of 50C to 50°C the specific heat is 0.217 calories per gram per degree centigrade. KDNBF is used in primary compositions.

b. Using a .45 kilogram (one pound) weight in the Picatinny Arsenal impact apparatus, the drop height is only six inches. In the pendulum friction test, KDNBF explodes with both the steel and fiber shoes. The minimum charge required for initiation is 0.30 grams of mercury fulminate or 0.10 grams of lead azide. The sensitivity of KDNBF is between that of mercury fulminate and lead azide.

c. In the sand test, 44.8 grams of sand are crushed, which indicates a brisance of 93 percent of TNT. The volume of gas developed on explosion is 604 cubic centimeters per gram.

d. In the 100°C heat test, the weight loss in the first 48 hours is 0.03 percent and in the second 48 hours 0.05 percent with no explosions in 100 hours. At 30°C and 90 percent relative humidity KDNBF is hygroscopic to the extent of 0.27 percent.

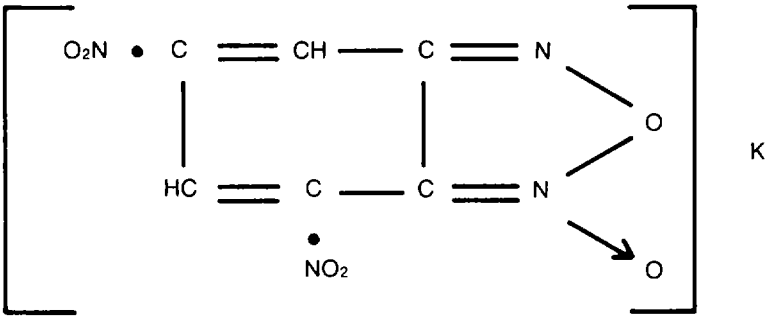


Figure 7-10. Structural formula for KDNBF.

e. The specifications for KDNBF are:

Color:	Light orange to dark red.
Bulk density:	0.2 grams per milliliter, minimum.
Forms:	KDNBF shall be in the form of plate-like crystals. In addition, the dried KDNBF powder shall be easily dispersible.
Granulation:	Through a No. 50 US standard sieve, 98 percent minimum. Retained on a No. 100 US standard sieve, 4 percent maximum. Retained on a No. 200 US standard sieve, 10 to 75 percent. Retained on a No. 270 US standard sieve, 85.0 to 100 percent.
Vacuum stability:	Not more than 1.0 milliliters of gas shall be evolved at 120° ± 0.5°C in 40 hours.
Nitrogen content:	19.75 percent-0.20 percent.
Differential thermal analysis:	The DTA graph of the tested KDNBF sample shall show only one major exotherm and that exotherm shall occur between 210°C and 225°C.
Nuclear magnetic resonance:	The NMR spectra of the tested KDNBF sample shall have five distinct peaks one each at 5.77, 5.93, 6.13, 6.27, and 8.63 ppm. The average amplitude of the peaks at 5.93 and 6.13 ppm shall be greater than thirty percent of the peak at 8.63 ppm. In addition, there shall be no peak at 9.22 ppm greater than five percent of the peak at 8.63 ppm.

7-8. Lead Mononitroresorcinate (LMNR).

a. LMNR (figure 7-11) has a nitrogen content of 3.89 percent, an NO_2 content of 12.77 percent, a lead content of 57.51 percent, and a molecular weight of 360.30. The compound forms microscopic reddish brown crystals. LMNR has slow burning properties and a low combustion temperature. The compound is used in electric detonators with DLA as the spot charge to initiate a PETN base charge, as an upper charge, and as an ingredient in primary compositions.

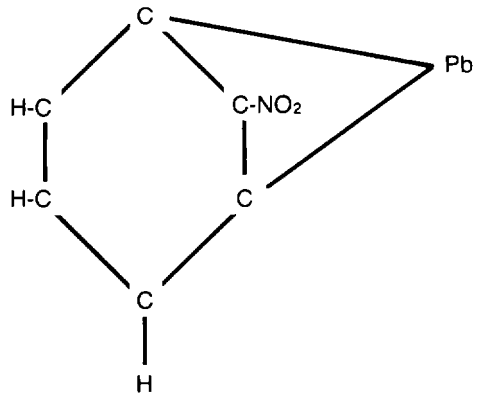


Figure 7-11. Structural formula for LMNR.

b. LMNR is prepared by mononitrating recorcinol then allowing the slurry of mononitrorecorcinol to react with $Pb(OH)_2$ at elevated temperatures. The LMNR is stored and transported under water with not less than 10 percent denatured alcohol.

c. LMNR must meet the following requirements for military use:

Color and appearance:	LMNR shall be light brown in color.
Apparent density:	0.20 to 0.35 grams per milliliter.
Acidity:	The pH shall be between 5.0 and 6.5 for a solution of one gram of the material in 150 milliliters of water.
Lead content:	70.5 to 72.5 percent.
Nitro group content:	7.2 to 7.6 percent.
Vacuum stability at 120°C:	0.4 milliliters of gas in 40 hours with a 2.3 gram sample, maximum.

7-9. Primary Compositions.

a. Primary compositions are mixtures of primary explosives, fuels, oxidizers, and other ingredients used to initiate detonation in high explosive charges or ignite propellants and pyrotechnics. The ingredients and the portions of the ingredients for individual priming compositions are determined empirically from the use the composition is intended for. Fuels commonly used in priming compositions are lead thiocynate, antimony sulfide, and calcium silicide. The last two also serve to sensitize the composition to friction or percussion. Oxidizing agents include potassium chlorate and barium nitrate. Other ingredients include primary explosives and binders. The major determining factor in ingredient selection is the impetus which is to detonate the priming composition. The types of impetus commonly used are percussion and electrical.

b. Percussion type primers are used extensively for the ignition of propellants. In the early 1900's this type of priming composition contained mercury fulminates. At the present time, however, mercury fulminate has been replaced by more stable compounds. Potassium chlorate was used in this type of priming composition from about 1917 through World War II. Except for special applications, the use of this compound has been discontinued because of the corrosive action of potassium chloride, a decomposition product of potassium chlorate, on gun barrels. Potassium chlorate is still used in high temperature priming compositions. Table 7-7 lists the composition of two such mixtures. The percentages listed are by weight. Table 7-8 lists several commonly used percussion priming compositions.

Table 7-7. High Temperature Percussion Primers

	G-11	G-16
Potassium chlorate, %	53	53
Antimony trisulfide, %	25	30
Calcium silicide, %	12	17
Temperature resistant explosive, %	10	-

Table 7-8. Percussion Priming Compositions

	Composition		
	FA959	FA982	FA956
Normal lead styphnate, %	35	36	37
Tetracene, %	3.1	12	4
Barium nitrate, %	31	22	32
Antimony sulfide, %	10.3	7	15
Powdered zirconium, %	10.3	9	
Lead dioxide, %	10.3	9	
PETN	-	5	5
Aluminum,	-	-	7
Gum arabic	-	-	0.2 (added)
Autoignition temperature	199°C	240°C	184°C
Decomposition temperature	209°C	262°C	193°C

Table 7-8. Percussion Priming Compositions (Continued)

	Composition		
	FA959	FA982	FA956
Density in grams per cubic centimeter	1.3-2.3(bulk)	1.4-2.4	1.3-2.4
Fuel to oxidizer ratio	0.5 to 1	0.52 to 1	0.69 to 1
Gas volume produced	5-10 milliliters per gram	5-10 milliliters per gram	5-10 milliliters per gram
Electrical spark sensitivity	< 0.05 joules		
Friction sensitivity	yes		

The output of percussion type primers includes hot gases, hot particles, thermal radiation, and a pressure pulse. In some cases the pressure pulse may be a shock wave.

c. Stab detonators are used to directly initiate secondary explosives. As the name implies, a stab detonator is initiated by penetration of a firing pin. The mechanical energy of the firing pin is converted to heat, which causes detonation. Rather than using one homogenous priming mixture as percussion type primers do, stab detonators contain three layers of charges; primary, intermediate, and base. Priming compositions used in the primary charge are shown in table 7-9. The intermediate charge is an energetic material such as lead azide or black powder. The base charge may be lead azide, black powder, or a more brisant explosive such as RDX or PETN. The base charge initiates the secondary explosive.

d. Electrical primers are of several types:

(1) exploding bridge wire
(2) hot wire bridge
(3) film bridge
(4) conductive mixture
(5) spark gap

Table 7-9. Stab Detonator Priming Compositions

	Composition		
	NOL 130	PA101	NOL 60
Lead azide, %	20		
Basic lead styphnate, %	40	53	60
Tetracene, %	5	5	5
Barium nitrate, %	20	22	25
Antimony sulfide, %	15	10	10
Powdered aluminum, %	-	10	-
Autoignition temperature	274°C	196°C	210°C
Decomposition temperature	280°C	215°C	227°C
Density in grams per cubic centimeter	1.85 (loading)	1.3-2.0	1.3-2.0
Fuel to oxidizer ratio	0.75 to 1	0.91 to 1	0.4 to 1
Gas volume produced	10-25 milliliters per gram	5-10 milliliters per gram	5-10 milliliters per gram
Electrical spark sensitivity	0.0022 joules	<0.05 joules	0.0022 joules
Friction sensitivity	yes	yes	yes
Hygroscopic	yes	yes	yes

In an exploding bridge wire detonator, a large current is passed through a wire which causes the wire to burst. The bursting of the wire causes a shock wave that is of sufficient strength to cause detonation. With this type of primer no priming composition is used; the wire is placed directly in a charge of RDX or PETN. Hot wire bridges and film bridges use priming compositions. Examples are listed in table 7-10. In these detonators the wire or film is heated by an electric current. The heat causes ignition of the charge which may then undergo a deflagration to detonation transfer. The functioning of a conductive mixture or spark gap primer is readily apparent from the name. These two types of primers are not commonly used.

Table 7-10. Electric Priming Compositions

	Composition					
	I	**II**	**III**	**IV**	**V**	**VI**
Potassium chlorate, %	8.5	55	25	60	66.7	66.7
Lead mononitroresorcinate, %	76.5	-	-	-	-	-
Nitrocellulose, %	15.0	-	-	-	-	-
Lead thiocynate, %	-	45	-	-	-	-
DDNP, %	-	-	75	20	-	-
Charcoal, %	-	-	-	15	-	-
Nitrostarch, %	-	-	-	5	-	-
Titanium, %	-	-	-	-	-	33.3
Aluminum, %	-	-	-	-	-	33.3
Autoignition temperature	244°C	203°C	396°C	396°C	475°C	446°C
Decomposition temperature	296°C	240°C	451° C	442°C	486°C	465°C
Density in grams per cubic centimeter	1.9-2.6	1.6-2.2	1.6-2.2	1.6-2.4	2.16-2.36	0.6
Fuel to oxidizer ratio	0.9 to 1	0.82 to 1	0.3 to 1	0.25 to 1	0.5 to 1	0.5 to 1
Gas volume produced	-	-	148 milliliters per gram	96 milliliters per gram	286 milliliters per gram	150 milliliters per gram

CHAPTER 8
UNITED STATES BOOSTER AND SECONDARY EXPLOSIVES

8-1. Introduction. This chapter contains discussions of military high explosive compounds. The explosives are arranged by chemical class. The chemical, physical, and thermochemical characteristics, sensitivity, performance, and stability are discussed for each explosive. The chemical structure of each compound is given, and for composition explosives, the ingredients are given. The method of manufacture is also given.

8-2. Aliphatic Nitrate Esters. Compounds in this class are prepared by O-type nitration in which a nitro group is attached to an oxygen atom of the compound being nitrated.

a. *1,2,4-Butanetriol Trinitrate (BTN).* This explosive is also known as α, β, γ- trihydroxybutane trinitrate and is sometimes referred to as BTTN. The compound (figure 8-1) is a light yellow liquid with a density of 1.520 at 20°C, a molecular weight of 241, a melting point of -27°C, an oxygen balance to CO_2 of 17 percent, and a refractive index of 1.4738 at 20°C. The liquid has a viscosity of 62 centipoises at 20°C. 1,2,4-Butanetriol trinitrate is slightly soluble in water, miscible with alcohol, ether, acetone, and a solution of 2 parts ether and 1 part alcohol. BTN has a heat of formation of 368 calories per gram, a heat of combustion of 2,167 calories per gram, and a heat of detonation of 1,458 calories per gram. This compound is a good gelatinizer for nitrocellulose and can be used as a substitute for nitroglycerin in double-base propellants. Heat, vacuum stability, and volatility tests indicate more stability than nitroglycerin. Impact sensitivity is about the same as for nitroglycerin. Brisance, as measured by the sand test, is about the same: 49 grams crushed versus 51.5 grams for nitroglycerin or 47 grams for TNT. The five second explosion temperature is 230°C versus 220°C for nitroglycerin. BTN can be manufactured by the nitration of 1,2,4-butanetriol with a mixture of nitric and sulfuric acids.

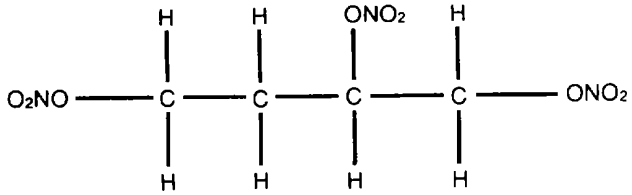


Figure 8-1. Structural formula for BTN.

b. Diethyleneglycol Dinitrate (DEGN).

(1) This explosive is also known as dinitrodiglycol or 2,2'-oxybisethanol dinitrate and is sometimes referred to as DEGDN. The compound (figure 8-2) is a clear, colorless, odorless liquid with a nitrogen content of 14.29 percent, a theoretical maximum density of 1.39 grams per cubic centimeter, an oxygen balance to C02 of-41 percent, and a molecular weight of 196. DEGN boils between 160° and 161°C and can, upon cooling, form a stable solid with a melting point of 2°C or remain liquid to a freezing point of -11.2° to 11.40°C. Other characteristics of the liquid are: refractive index at 20°C with sodium light, 1.450; viscosity at 20°C, 8.1 centipoises; vapor pressure at 20°C, 0.0036 torr; vapor pressure at 25°C, 0.00593 torr; vapor pressure at 600C, 0.130 torr; specific gravity, 1.385. At 60°C DEGN has a volatility of 0.19 milligrams per square centimeter per hour. At constant pressure, the heat of combustion is 2,792 calories per gram. The heat of formation is-99.4 kilogram calories per mole. The heat of detonation is 1,161 calories per gram. DEGN is readily soluble in ether, acetone, chloroform, benzene, nitrobenzene, toluene, nitroglycerin, and glacial acetic acid but is insoluble in ethanol, carbon tetrachloride, and carbon disulfide. Solubility in water at 25°C and 60°C is 0.40 and 0.46 gram per 100 grams, respectively. DEGN's chemical reactivity is similar to nitroglycerin's, but is less subject to hydrolysis and is not readily saponified by alcoholic sodium hydroxide. DEGN can be used as an explosive and can be used in propellants as a colloiding agent for nitrocellulose. Propellants based on DEGN and nitrocellulose develop relatively low temperatures and cause relatively little erosion of guns, but are unduly volatile.

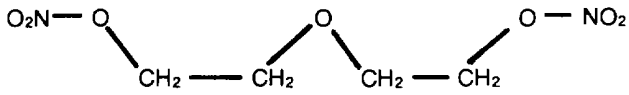


Figure 8-2. Structural formula for DEGN.

(2) DEGN can be manufactured with a yield of approximately 85 percent of the theoretical by adding diethylene glycol to mixed acid containing approximately 50.3 percent nitric acid, 44.7 percent sulfuric acid, and 5.0 percent water. The temperature of the mixture is kept at 10° to 15°C. The spent acid is very unstable and fumes off if heated or allowed to stand for a few hours. The separated DEGN is purified by washing with successive portions of water, dilute sodium carbonate solution, and water until neutral. The purity of the product is dependent mainly on the purity of the diethylene glycol used in the manufacturing process.

(3) DEGN is so insensitive that mixing with another nitrated compound is required to produce a useful explosive. DEGN alone, however, does explode in the pendulum friction test. The explosion temperature test value for DEGN is 237°C.

(4) As indicated by the vacuum stability tests, DEGN is much more stable than nitroglycerin at 100°C and will, when free from acidity, withstand long term storage at ordinary temperatures.

(5) The brisance of DEGN, as judged by the modified sand test, is equal to that of TNT and 81 percent that of nitroglycerin. At a density of 1.38 grams per cubic centimeter, DEGN's rate of detonation is 6,760 meters per second, slightly less than TNT's. The Trauzl lead block test indicates DEGN to be 144 to 150 percent as powerful as TNT and 77 percent as powerful as nitroglycerin. The ballistic pendulum test indicates DEGN to be 127 percent as powerful as TNT and 90 percent as powerful as nitroglycerin.

c. *Nitrocellulose (NC).*

(1) Nitrocellulose or cellulose nitrate is a mixture of nitrates obtained by nitrating cellulose. Cellulose (figure 8-3) is a long chain polymer of anhydroglucose units ($C_5H_{10}O_5$). The number of anhydroglucose units or degree of polymerization (DP) is variable. Cellulose used for preparation of military grades of nitrocellulose have a DP of approximately 1,000 to 1,500. Cellulose threads possess micellar structure and consist of numerous rod-like crystallites oriented with their long axis parallel to the thread axis, thus forming a fiber. Almost pure cellulose is found in the pith of certain plants, in absorbent cotton, and in some filter papers. Pure cellulose is most readily obtained from cotton by treating with a dilute acid or base solution then thoroughly washing with water. At the present time most of the cellulose for nitrocellulose preparation is obtained from coniferous wood, which is 50 to 60 percent cellulose. Another source is straw, which is 30 to 40 percent cellulose. The nitration of cellulose involves replacement of the hydrogen in the three hydroxyl (OH) groups in the anhydroglucose units with NO_2 groups. A representative formula for the nitrated cellulose may be written as $C_6H_7(OH)x\ (ONO_2)\ y$ where $x+ y=3$. The mononitrate, x =2 and y =1, has a nitrogen content of 6.76 percent; the dinitrate, x=1 and y =2, has a nitrogen content of 11.11 percent; the trinitrate, x =0 and y =3, has a nitrogen content of 14.14 percent. As a practical matter, however, any desired degree of nitration up to 14.14 percent may be obtained by adjusting the composition of the mixed acid used for nitration, the acid to cellulose ratio, the time of nitration, or the temperature of nitration. In nitrocellulose with less than 14.14 percent nitrogen, the NO2 groups are distributed randomly along the entire length of the cellulose polymer, so x and y should be regarded as average values over the entire length of the chain. The nitrogen content determines the chemical and physical properties of any particular nitrocellulose. The five grades of nitrocellulose listed below are recognized and used.

(a) Pyroxylin or collodion, which contains from about 8 to 12.3 percent nitrogen, is light yellow, matted filaments. The theoretical maximum density is 1.653 grams per cubic centimeter, the melting point with decomposition is greater than 135°C, and the heat of formation is -216 kilocalories per mole for pyroxylin with a nitrogen content of 12 percent. When dissolved in 3 parts ether and 1 part alcohol, the solution is pale yellow and viscous. Pyroxylin is also soluble in acetone or glacial acetic acid, and is precipitated from solution by water. When thin layers of solutions are permitted to evaporate, the pyroxylin forms a tough, colorless film. Pyroxylin is very flammable and is decomposed by light. The pyroxylin used for the manufacture of celluloid contains 11.0 to 11.2 percent nitrogen, while that used in the manufacture of blasting explosives has a nitrogen content of 11.5 to 12.0 percent. The pyroxylin used for military purposes contains 12.20 ±0.10 percent of nitrogen. Pyroxylin with 11.13 percent nitrogen is hydrolyzed to the extent of 1.71 percent of the available nitrogen after 240 hours of boiling in water. The heat of detonation of pyroxylin with a nitrogen content of 12 percent is 1.16 kilocalories per gram for liquid water and 1.02 kilocalories per gram for gaseous water.

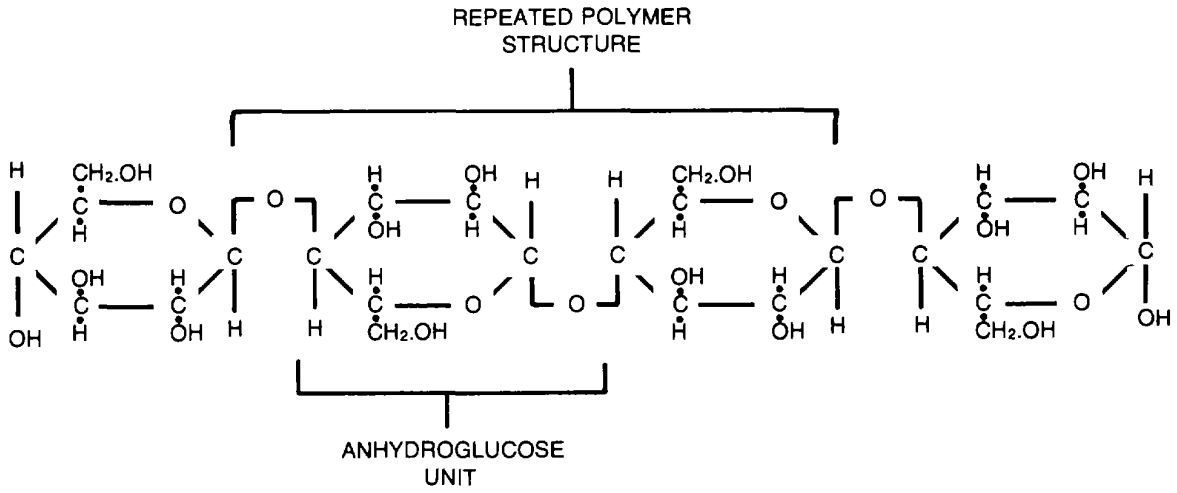


Figure 8-3. Cellulose.

(b) Pyrocellulose is a type of nitrocellulose which has a nitrogen content of 12.60±0.10 percent. Pyrocellulose is insoluble in water and ether but 99 percent dissolves in a solution of 2 parts ether and 1 part alcohol, 21 percent dissolves in ethyl nitroacetate, and 11 percent dissolves in alcohol. Pyrocellulose is soluble in acetone, ethyl acetate, methyl acetate, propylene oxide, nitromethane, and nitroethane but solubility is not limited to these. Pyrocellulose is used as a propellant and in propellant mixtures. Pyrocellulose with 12.6 percent nitrogen is hydrolyzed to the extent of 1.22 percent of the available nitrogen after 240 hours of boiling in water. The specific heat of pyrocellulose with a nitrogen content of 12.6 percent is 0.3478 calories per gram per degree centigrade at 25°C.

(c) Guncotton is the grade of nitrocellulose that contains the highest percentage of nitrogen obtainable by nitrating cellulose with mixed nitric and sulfuric acids. The percentage of nitrogen is 13.35 to 13.45 percent. The theoretical maximum density is 1.656 grams per cubic centimeter, the melting point with decomposition is greater than 135°C, and the heat of formation is-200 kilocalories per mole for guncotton with a nitrogen content of 13.35 percent. Guncotton is insoluble in water and ether, very slightly soluble in alcohol, about 4 to 10 percent soluble in a solution of 2 parts ether and 1 part alcohol, and soluble in acetone, ethyl acetate, and other organic solvents. Guncotton is used as a propellant and as a primer in electric detonators. Guncotton with 13.44 percent nitrogen is hydrolyzed to the extent of 1.03 percent of the available nitrogen after 240 hours of boiling in water. The heat of detonation of guncotton with a nitrogen content of 13.35 percent is 1.16 kilocalories per gram for liquid water and 1.02 kilocalories per gram for gaseous water. The specific heat of guncotton with a nitrogen content of 13.4 percent is 0.3408 calories per gram per degree centigrade at 25°C.

(d) High nitrogen nitrocellulose is the grade of nitrocellulose that contains from 13.75 to 14.14 percent nitrogen. The theoretical maximum density is 1.659 grams per cubic centimeter and the heat of formation is-191 kilocalories per mole for nitrocellulose with a nitrogen content of 14.14 percent. The compound is insoluble in water, ether, n-propyl alcohol, and isopropyl alcohol, but about 0.6 percent soluble in ethanol, 1 percent soluble in methyl alcohol, 1.4 percent soluble in a solution of 2 parts ether and 1 part alcohol, 20 percent soluble in methyl acetate, 42 percent soluble in nitromethane, 86 percent soluble in 1-nitropropane, and 100 percent soluble in acetone, ether acetate, propylene oxide, and amyl acetate. High nitrogen nitrocellulose can be used in the preparation of propellants with higher ballistic potential than guncotton, but it is not used in U.S. standard propellants because it is too costly to manufacture. The heat of detonation for nitrocellulose with a nitrogen content of 14.14 percent is 1.95 kilocalories per mole for liquid water and 1.81 kilocalories per mole for gaseous water. The specific heat for nitrocellulose with a nitrogen content of 14.14 percent is 0.3362 calories per gram per degree centigrade.

(e) Blended nitrocellulose is a mixture of 60 to 65 percent guncotton and 35 to 40 percent pyrocellulose. The guncotton should have a nitrogen content of 13.4 percent and the pyrocellulose nitrogen content should be 12.6 percent. Straight guncotton has a higher ballistic potential than blended nitrocellulose but is only slightly soluble in an ether-alcohol solution, the mixture most commonly used in the United States to colloid nitrocellulose. Blended nitrocellulose of the proportions given above is soluble to the extent of about 37 ± 2 percent in a mixture of 2 parts ether and 1 part alcohol. This property makes blended nitrocellulose suitable as a single-base propellant. Two grades of nitrocellulose are commonly used: one with a nitrogen content of 13.15-±0.05 percent and one with a nitrogen content of 13.25±0.05 percent.

(2) X-ray diffraction studies have yielded the following information regarding the nitration of cellulose. In the first stage of nitration, nitric acid penetrates the entire cellulose structure. The amorphous part of the cellulose is more reactive than the crystalline part, so the second stage involves nitration of the amorphous part. At the same time the micellar arrangement is being broken down. The third stage of nitration involves the swelling and breakdown of the micellar arrangement. Swelling takes place as shown in figure 8-4. The nitrating agent, as is the case with any esterifying reagent, attacks one end of the micelle and causes a gradual sliding apart of the chain as nitration proceeds. When 12.2 percent nitrogen content is reached, an orderly arrangement of the chains becomes possible and there is a sudden appearance of the trinitrate crystalline structure. The nitration of cellulose is a reversible reaction, proceeding as:

$$(C_6HO_2)(OH)_3 + xHNO_3(C_6H_7O_2) \rightleftharpoons (OH)_3\text{-}y\,(ONO_2)\,y + xH_2O$$

where *y* varies between 0 and 3 over the length of the polymer. Therefore, an equilibrium exists for each concentration of nitrating acid, which corresponds to a definite degree of nitration, provided all other conditions, such as temperature and pressure, remain the same. This means that if the concentration of nitrating bath containing nitrocellulose nitrated to a certain nitrogen content, is slightly weakened by the addition of water, the reaction will go from right to left and nitrocellulose will be partly hydrolyzed to the nitrogen content corresponding to the concentration of the new nitrating bath. This reaction is known as denitration. The rate of denitration is insignificant if the acid is rapidly diluted to a very low concentration and cooled at the same time as, for example, when nitrocellulose wet with acid is drowned in a large amount of ice water. If, on the other hand, drowning is done into a small amount of water and the temperature is allowed to rise, a certain amount of denitration takes place. During the wringing operation, which removes the spent mixed acid, if the nitrocellulose is left in contact with a humid atmosphere longer than usual, considerable denitration takes place, especially in the outer layers of the wrung nitrocellulose.

(3) A point should be made here regarding the mechanism of solubility of nitrocellulose. As a general rule, solvents for polymers like nitrocellulose act at first as swelling agents and only afterwards as dispersing reactants. The fibrous structure of nitrocellulose is not lost when swelling compounds such as cyclohexanone, fenchone, and meta-xylene are used. When nitrocellulose is treated with a solvent a gel is obtained and the phenomena known as gelatinization occurs. A volatile solvent can be evaporated in order to obtain a plasticlike colloided material. A smokeless nitrocellulose propellant processed with the aid of an ether-alcohol mixture is an example. If the solvent is nonvolatile or only slightly volatile, the nitrocellulose forms a gel, but usually heat is required for completion of the operation. A double-base, solventless, smokeless propellant is an example. If heating is undesirable because of danger, gelatinization can be achieved by blending nitrocellulose at room temperature with a gelatinizer dissolved or suspended in a liquid, such as alcohol, which is not necessarily a solvent for nitrocellulose. If a solid solvent such as camphor is used in the preparation of celluloid, the water-wet nitrocellulose is mixed with powdered camphor, some alcohol is added, and the mass is kneaded at room temperature for several hours. The process is usually called plasticization. Both gelatinization and plasticization yield similar materials which are flexible and crack resistant. The difference is a gelatinizer tends to draw the molecules together and a plasticizer spreads them out. The solubility of nitrocellulose in organic solvents and the formation of gels is attributed to formation of molecular addition compounds between nitrocellulose and the solvent.

(4) In the manufacture of nitrocellulose, the first step is the pretreatment of the cellulose. Short fibered cotton or cotton linters that have been suitably purified by washing with water are dried at 105° to 110°C until the moisture content is reduced from 6 to 7 percent to about 0.5 percent. If the starting material is wood pulp, the pulp sheets are fed into a drier maintained at 110° to 115°C. During a drying time of about 15 minutes, the moisture content is reduced from 4 to 5 percent to about 0.5

percent. The dried pulp sheets pass from the drier into a shredder where they are reduced to pieces about five millimeters in length. In storage, the cellulose should be kept in airtight containers to prevent moisture from being absorbed. The cellulose is nitrated by the mechanical dipper process which has displaced other, more hazardous processes. The composition of the mixed acid used in this process varies depending on the type of cellulose nitrated, the degree of nitration desired, and the season of the year. Higher temperatures cause denitration of the mixed acid, so the nitric acid content must be greater during the summer than during the winter. Table 8-1 lists typical compositions of mixed acid.

Table 8-1. Compositions of Mixed Acids for Nitrating Cellulose

	For pyrocellulose from -		For guncotton from -		For high nitrogen nitrocellulose	
	Cotton linters Percent	Wood pulp cellulose Percent	Cotton linters Percent	Wood pulp cellulose Percent	13.8%N Percent	13.8%N Percent
Sulfuric acid	59.2	57.0	60.5	59.5	-	-
Nitric acid	21.5	23.5	24.5	28.5	49	70-85
Nitrosylsulfuric acid	3.5	4.4	4.0	3.0	-	-
Water	15.8	15.1	11.0	9.0	-	-
Phosphoric acid	-	-	-	-	49	-
Phosphoric anhydride	-	-	-	-	2	-
Ammonium nitrate	-	-	-	-	-	15-20
or potassium nitrate	-	-	-	-	-	or 30

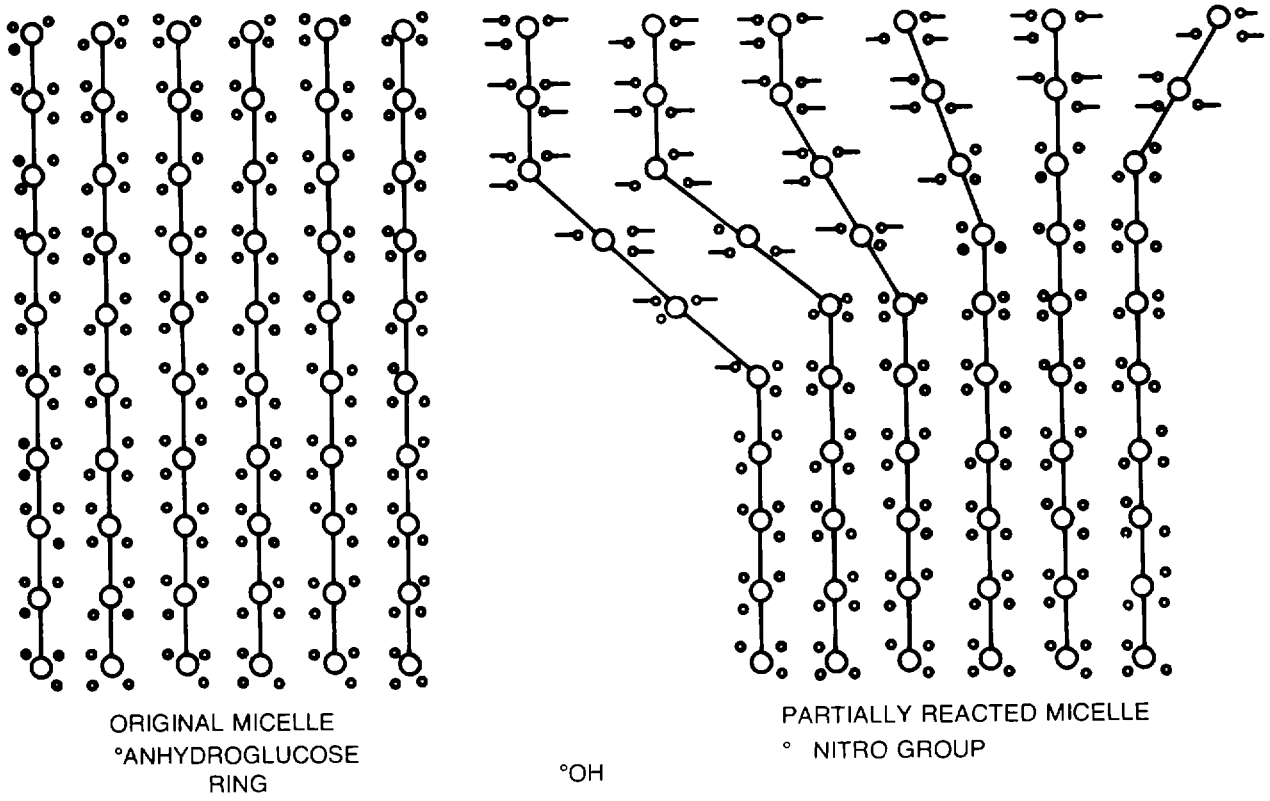


Figure 8-4. Nitration of cellulose.

About 1,500 pounds of mixed acid are placed in a stainless steel nitrator at a temperature of 30°C. The nitrator is equipped with two vertical agitators revolving in opposite directions that impart motion toward the center. Approximately 32 pounds of cellulose are added. The paddles of the agitator are designed to immediately draw the cellulose below the surface of the acid, away from the fume exhaust line. The addition of the cellulose requires about four minutes; agitation is then continued for twenty minutes. Nitration is exothermic, so provisions must be made to prevent the temperature from rising above 300C. When nitration has been completed, the slurry is discharged through a valve in the bottom to a centrifuge, called a wringer, where most of the mixed acid is removed. The composition of the spent acid can be adjusted if the acid is to be reused in nitration. The acid-wet, crude nitrocellulose is then forked through an opening in the bottom of the wringer into a drowning basin where rapid submersion in cold water takes place. The nitrocellulose must then be stabilized and purified. High nitrogen nitrocellulose can be prepared in the following additional ways. Guncotton wetted with 25 percent water can be nitrated to 14 percent nitrogen content by a mixed acid containing either 60 percent nitric acid, 20 percent acetic acid, and 20 percent acetic anhydride or 50 percent nitric acid, 25 percent acetic acid, and 25 percent acetic anhydride. This process yields nitrocellulose with 14 percent nitrogen of low viscosity which is suitable for military use. Other nitrating agents may be used to produce different percentages of nitrogen. Another method of nitration is to heat concentrated nitric acid to form N_2O_5 vapors which are passed over cellulose in the shape of paper rolls. This process yields a 14 percent nitrogen content.

(5) Removal of the impurities in the raw nitrocellulose is critical to obtain a product with suitable stability. Acids and other impurities are absorbed on the fibers of the nitrocellulose and are hard to remove. The first step in the process, called the sour boil, is carried out in large cypress wood tubs equipped with ducts for heating and circulating water at approximately 100°C. During the first two hours, the acidity of the water is adjusted to 0.05 to 0.50 percent, calculated to H_2SO_4. Pyrocellulose and pyroxylin are subjected to 40 hours of boiling treatment with three changes of water during this period. Guncotton is subjected to 60 hours of boiling treatment followed by two five-hour boiling treatments with a change of water after each treatment. The next step in the process is pulping. Because cellulose fibers are tubular, having capillary channels running through them, part of the impurities present in guncotton are included in these channels and cannot be removed unless the fibers are cut into very short fragments. This operation is done in an apparatus called a beater, or Jordan engine similar to that employed in the paper industry. The beating operation is carried out with a large volume of water with just enough sodium carbonate solution added to preserve a slightly alkaline reaction to phenolphthalein. Beating is continued until the nitrocellulose has been reduced to the desired degree of fineness, as determined by a settling test. After the slurry from the beater has been settled and decanted, the nitrocellulose is subjected to poaching. Poaching consists of one four-hour, one two-hour, and two one-hour boiling treatments with settling, decantation, and the addition of fresh water after each treatment. In the four-hour boiling treatment, sodium carbonate equaling 0.5 percent of the weight of dry nitrocellulose is added. The poaching treatment is followed by not less than two washes with cold water, each wash consisting of agitation of the nitrocellulose with fresh water for at least half an hour. The next step in the process is called screening. Uniformity of characteristics is difficult to obtain in the various batches of nitrocellulose. To ensure uniform characteristics in the final product, portions of batches having high nitrogen content and high viscosity are mixed with portions having low nitrogen content and viscosity. The resulting mixtures possess properties intermediate between those of the individual batches. The mixed slurry is fed through a distributor which spreads the nitrocellulose uniformly on packer screens. The screen, with 0.02 inch slots, is vibrated mechanically and the properly pulped nitrocellulose passes through the screen into collecting boxes. If a blended nitrocellulose is desired, blending is the next step in the manufacturing process. Each blending unit consists of two tubs, equipped with propeller type agitators, interconnected so that the contents are kept in constant circulation. The receiving tub, or high tub, is filled with slurry from the screening operation so that the overflow discharges into the low tub. When the low tub is partially full, a circulating pump is started and part of the slurry is returned from the low tub to the high tub. This process is continued for 6 to 7 1/2 hours after which time a sample is tested for nitrogen content and solubility in a solution of 2 parts ether and 1 part alcohol. The last step in the

manufacture of nitrocellulose is wringing. Nitrocellulose from the screening or blending process is placed in a centrifugal wringer with a perforated brass basket lined with a 24 mesh copper screen. The basket revolves at 950 rpm for about seven minutes. The wrung nitrocellulose, with a moisture content of about 31 percent is stored in rustproof metal cans with tight fitting covers.

(6) Dry nitrocellulose is very sensitive to impact, friction, heat, and spark and is never handled in quantity in the United States. The results of impact sensitivity tests for all types of nitrocellulose are approximately 8 centimeters, which indicates nitrocellulose is 460 percent as sensitive as TNT or about the same as mercury fulminate and lead azide. Rifle bullet impact tests indicate nitrocellulose to be very sensitive with 100 percent of the trials yielding complete detonations. While the five second explosion temperature test value for pyrocellulose (170°C), blended nitrocellulose (200°C), and guncotton (230°C) are not particularly low, the rapid rate of decomposition of the material at temperatures greater than 100°C and the exothermicity of such decomposition make the material very sensitive to ignition by a spark. Nitrocellulose can be detonated even when wet. A mixture of 60 percent nitrocellulose and 40 percent water confined in a steel barrel sometimes is detonated by a stick of dynamite. The frequency of detonation is greater when the water is frozen. Tests have shown that nitrocellulose uniformly wetted with 35 percent ethanol will also detonate, on occasion, when initiated with dynamite.

(7) The brisance of nitrocellulose, as determined by the sand test, is directly comparable with TNT but less than tetryl. The brisance of nitrocellulose increases with increases in the nitrogen content. The rate of detonation of guncotton with a nitrogen content of 13.45 percent and density of 1.2 grams per cubic centimeter is 7,300 meters per second; greater than that of TNT. As nitrocellulose propellants can be detonated as well as burned, their brisance values are high. Trauzl lead block tests show guncotton (13.2 to 13.4 percent nitrogen) to be 136 to 147 percent as powerful as TNT and the ballistic mortar test indicates guncotton is 118 percent as powerful as TNT.

(8) The great care taken in the purification of nitrocellulose is due to the necessity for removing impurities that are much less stable than the nitrocellulose. Cellulose sulfate is unstable with respect to heat and moisture. Propellants made from nitrocellulose containing even comparatively small amounts of such esters give decreased 134.5°C heat test values and deteriorate more rapidly. The nitrates of oxidized cellulose are also objectionable and cause increased instability of nitrocellulose if not removed during the purification process. Elevated temperature tests show that even nitrocellulose of high purity is much less stable than most of the noninitiating military high explosives. The stability of pyrocellulose and blended nitrocellulose is 35 minutes, minimum, by the 65.5° KI test and 30 minutes, minimum, by the 134.5°C heat test. Figure 8-5 shows the DTA and pyrolysis curves for nitrocellulose. Vacuum stability tests indicate the stability of nitrocellulose decreases with increasing nitrogen content. For nitrocellulose with a nitrogen content of 12 percent, 5.0 cubic centimeters of gas are evolved in 48 hours at 120°C. In the LLNL reactivity test, 1.0 to 12 cubic centimeters of gas are evolved per .25 grams of sample. Nitrocellulose appears to undergo very slow decomposition even at ordinary temperatures. The rate of decomposition increases 3.71 times with each 10°C increase in temperature. The presence of moisture increases the rate of decomposition considerably and the presence of free acid or alkali has an even more pronounced effect. Rates of decomposition of pyrocellulose under various conditions are shown in table 8-2.

Table 8-2. Decomposition of Nitrocellulose

Decomposition medium	Percent available nitric acid liberated per hour at -	
	50°C.	97.5°C.
Heat	0.0000045	0.0028
Water	0.0000111	0.0051
0.06 Percent nitric acid solution	0.0000325	
0.035 Percent nitric acid solution	-	0.0088
0.035 Percent sodium carbonate solution	0.0006870	0.1358
95 Percent ethanol	0.0000290	-

From these data, it is apparent that alkali is more effective than acid in causing the deterioration of nitrocellulose. Pyrocellulose is hygroscopic to the extent of 3 percent at 30°C and 90 percent relative humidity. Under the same conditions blended nitrocellulose, 13.15 percent nitrogen, is hygroscopic to the extent of 2.5 percent, guncotton, 13.45 percent nitrogen, to 2 percent, and high nitrogen nitrocellulose, 14 percent nitrogen, to 1 percent.

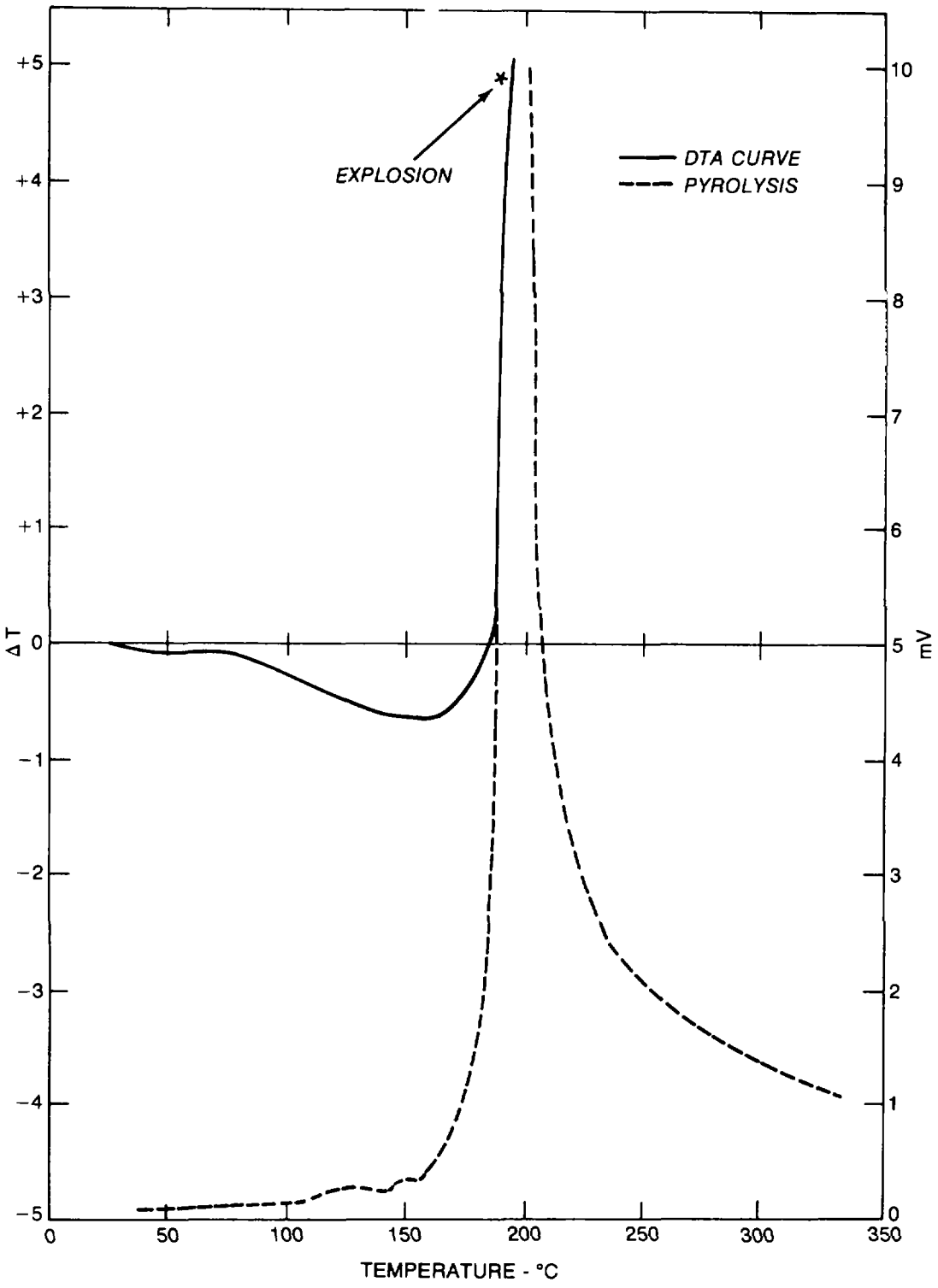


Figure 8-5. DTA curve for nitrocellulose.

(9) Military grades of nitrocellulose are:

	Class	*Nitrogen, percent*
Grade A	Pyrocellulose	
Type I		12.60±0.10
Type II		12.60±0.15
Grade B	Guncotton	13.35 minimum
Grade C	Blended	
Type I		13.15±0.05
Type II		13.25±0.05
Grade D	Pyroxylin	12.20 ±0.10
Grade E		12.00±0.10

The maximum allowable ash left after ignition of the nitrocellulose in any grade is 0.4 percent. The minimum percentage that is insoluble in ether alcohol in grades A, D, and E is 99 percent. The solubility limit for grade C in ether alcohol is left to discretion of the contractor manufacturing propellants from the nitrocellulose.

d. *Nitroglycerin (NG).*

(1) Nitroglycerin, glycerol trinitrate, or 1,2,3-propanetriol trinitrate, shown in figure 8-6, is a clear, colorless, odorless, oily liquid with a theoretical maximum density of 1.596 grams per cubic centimeter. Nitroglycerin has a sweet, burning taste and a molecular weight of 227.1.

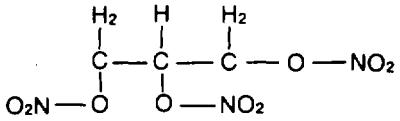


Figure 8-6. Structural formula for nitroglycerin.

(2) Pure nitroglycerin freezes to form dipyramidal rhombic crystals with a heat of crystallization of 33.2 calories per gram. This is a stabile form with a freezing point of 13.2°C and melting point of 13.5°C. Under some conditions, glassy triclinic crystals with a heat of crystallization of 5.2 calories per gram are formed. This is a labile form with a freezing point of 2.1°C and a melting point of 2.8°C. The labile form gradually changes into the stabile form after a week or two with a heat of conversion of 28 calories per gram. Nitroglycerin has an apparent boiling point of 145°C, but this is merely the temperature at which nonexplosive decomposition becomes vigorous enough to resemble boiling. True boiling takes place at reduced pressure; at 2 torr the boiling point is 125°C and at 50 torr the boiling point is 180°C. Even under high vacuum boiling, however, some decomposition takes place.

(3) Nitroglycerin has a specific gravity value of 1.596 20/15 and a refractive index value of 1.4732 at 20°C. Viscosity values are 0.36, 0.21, 0.094, and 0.068 poise at 20°, 30°, 50°, and 60°C, respectively. The vapor pressure values for nitroglycerin in torr are 0.0013 at 1 5°C, 0.0015 at 20°C, 0.00177 at 25°C, 0.00459 at 35°C, 0.0075 at 40°C, 0.01294 at 45°C, 0.03587 at 55°C, and 0.06 at 60°C. Decomposition begins at 50° to 60°C. Nitroglycerin is volatile to the extent of 0.11 milligram per square centimeter per hour at 60°C. The specific heat of nitroglycerin is 0.356 calories per gram per degree centigrade between 35°C and 200°C.

(4) The heat of detonation is 1,486 calories per gram for gaseous water and 1,590 for liquid water. One gram/mole of nitroglycerin produces 715 millititers/ 163.5 liters. The heat of formation is-90.8 kilocalories per mole.

(5) Nitroglycerin is soluble in one liter of water to the extent of only 0.173, 0.191, 0.228, and 0.246 gram at 20°, 30°, 50° and 60°C, respectively and is essentially nonhygroscopic when exposed to atmospheric humidity. Absolute ethanol dissolves 37.5 and 54 grams of nitroglycerin per 100 grams of solvent at 0° and 20°C, respectively. 96 percent alcohol dissolves 40 grams per 100 grams of solvent at 20°C. Carbon tetrachloride dissolves 20 milliliters per liter and trichloroethylene dissolves 20 parts per 100 parts of solution. Carbon disulfide at room temperature dissolves only 12.5 grams per liter of solvent. Hot ethanol and nitroglycerin are miscible in all proportions. Nitroglycerin is miscible in all proportions with ether, acetone, glacial acetic acid, ethyl acetate, benzene, toluene, phenol, nitrobenzene, chloroform, ethylene chloride, and nitric esters such as glycol dinitrate. Nitroglycerin can be used as a solvent for other explosives; 35 grams of dinitrotoluene dissolve in 100 grams of nitroglycerin at 20°C and 30 grams of trinitrotoluene dissolve per 100 grams at 20°C. Nitroglycerin is used extensively in propellant compositions as a gelatinizing agent for nitrocellulose as well as in dynamites and for the shooting of oil wells.

(6) Concentrated sulfuric acid decomposes nitroglycerin resulting in the formation of nitric acid. In the presence of metallic mercury, nitric oxide is formed quantitatively, and this reaction is the basis for determination of the purity of nitroglycerin by the nitrometer method. The reaction between nitroglycerin and aqueous sodium hydroxide is slow because of their immiscibility, but if ethanol is added the reaction is rapid. Sodium nitrate, nitrite, formate, and acetate are produced in this reaction and resinous material, oxalic acid, and ammonia are produced as byproducts. Nitroglycerin is hydrolysed to a very slight extent by water; producing less than 0.002 percent of acidity in 10 days

at 22°C or 0.005 percent of acidity in 5 days at 60°C. An aqueous solution of sodium sulfide decomposes nitroglycerin producing great heat. This reaction can be used for the destruction of waste material.

(7) Nitroglycerin is manufactured by nitrating glycerin with a mixed acid. Several processes are currently used in the United States and Europe. The processes can be generally classified according to whether they are continuous or batch production.

(a) In batch production, high grade glycerol is added to mixed acid that consists of 45 to 50 percent nitric acid and 50 to 55 percent sulfuric acid. The mixed acid is prepared well in advance to allow metallic sulfates to settle out. The metallic sulfates might otherwise interfere with separation of the nitroglycerin. Two important factors determine the proportions in the mixed acid. First, that the ratio of the sulfuric acid to water at the end of the reaction, the dehydrating value of the sulfuric acid or DVS, is maintained between 4.35 and 4.5. The water includes both the water in the original reactants and that produced during the reaction. This ensures that the nitric acid is maintained at a sufficient concentration to ensure completion of the reaction so that completely nitrated products that are subject to exothermic oxidation reactions are not formed. Second, that enough nitric acid is present to drive nitration, which is a reversible reaction, to completion. A slight excess of nitric acid will accomplish this. The reaction between the glycerol and mixed acid is carried out in a nitrator equipped with a mechanical agitator and cooling coils that carry a brine solution of calcium chloride at-20°C. A 6,800 pound charge of mixed acid is placed in the nitrator and the glycerol is added in a small stream. The mixed acid to glycerol ratio, by weight, is between 5.5 and 6.5. If too much glycerol is added, exothermic decomposition and oxidation reactions occur and temperature control becomes difficult. The temperature is maintained at 2° to 3°C by cutting off the flow of glycerol as necessary. If the temperature does rise above 3°C, the contents are drowned in a water tank beneath the nitrator. Stirring must be adequate to prevent freezing on the cooling coils. Stirring is continued for a few minutes after the 50 to 60 minutes required to add the glycerol. Then the nitroglycerin is allowed to separate completely. The lower layer of spent acid is drained off to be recycled or otherwise disposed of, and the nitroglycerin is run off into a neutralizer. An initial 40°C water wash removes most of the acid. Then a wash with a 2 to 3 percent sodium carbonate solution neutralizes the residual acid. Washing with water is continued until the water is free of alkali and the nitroglycerin is neutral to litmus. The final step in this manufacturing process is to wash with a sodium chloride solution to remove any nitroglycerin water emulsion. Moisture content gives the product a milky appearance, but on storage in a heated building, the material becomes clear and the moisture content decreases to 0.4 percent or less. The yield of nitroglycerin is 230 ±5 parts by weight per 100 parts of glycerin.

(b) The chemistry involved in the continuous manufacture of nitroglycerin is basically the same as that described for batch processing except the equipment is designed to allow nonstop production. The advantages of continuous processes are: faster production, better process control, lower labor costs, and, perhaps most important, safety, as a result of the smaller accumulations of nitroglycerin at any given plant location. In the United States the common practice is to nitrate mixtures of glycol and glycerol. The nitration proceeds in the same manner as with pure glycerol.

1 The Schmid-Meissner process (figure 8-7) involves continuous nitration of glycerin or other liquids, such as ethyleneglycol or diethyleneglycol, separation of the nitrated product from spent acid, and purification by neutralization and washing. The stainless steel nitrator is equipped with a motor driven, steel propeller, vertical cooling coils, and an overflow tube to separator. A two way valve, which may be connected to the mixed nitric-sulfuric acid line or may be opened to the drowning tank, is fitted centrally to the bottom of the nitrator. Brine at about-5°C is circulated at a controlled rate around the cooling tubes in the annular space outside the nitrator. As a measured amount, per unit time, of mixed acid is fed in from the bottom, a calculated amount of glycerin is fed in from the top at a level below that of the overflow pipe. The flow of materials into the nitrator is by means of automatically controlled air pressure. The propeller mixes the two liquids and glycerin is nitrated to nitroglycerin. The temperature in the nitrator is not allowed to exceed 18°C. The emulsion of nitroglycerin and spent acid flows off continuously through the overflow to the separator, which is a stainless steel, inclined, rectangular tank provided with a number of vanes, equipped with a bottom draw off valve for spent acid, a sight glass near the top, and a steel neck with overflow pipe for the nitroglycerin. Because of difference in density, the spent acid settles to the bottom of the separator and the nitrated product rises. The withdrawal of acid from the bottom is regulated to keep the separated nitrated product in the top of the separator at a predetermined level. The spent acid is discharged to the acid recovery plant and the nitroglycerin flows by gravity to the base of the first of the washing columns.

Each column consists of superimposed cylindrical glass sections (rings) separated by perforated stainless steel plates and rubber ring gaskets. The nitrated product from the separator enters the bottom of the first washing column, is mixed with cold water and emulsified by means of air injected into the liquid. This also forces the material to rise to the top of the column, where the emulsion overflows into a tank which serves as an intermediate separator. Here the nitrated product rapidly settles to the bottom, and flows to the base of the second wash column. In the second column the separated nitroglycerin is mixed with a hot dilute solution of soda and ammonia and then emulsified with air. The emulsion flows from the top of the column to another intermediate separator where the nitrated product settles to the bottom and is separated from the soda ash water, which is conducted to waste via settling tanks. Any nitroglycerin held in the tanks is drawn off periodically and rewashed. The nitrated product is subsequently passed through additional wash columns and separators until the desired stability is attained. Finally the purified product is passed through a flannel filter bag before being caught in a lead tank for storage and use.

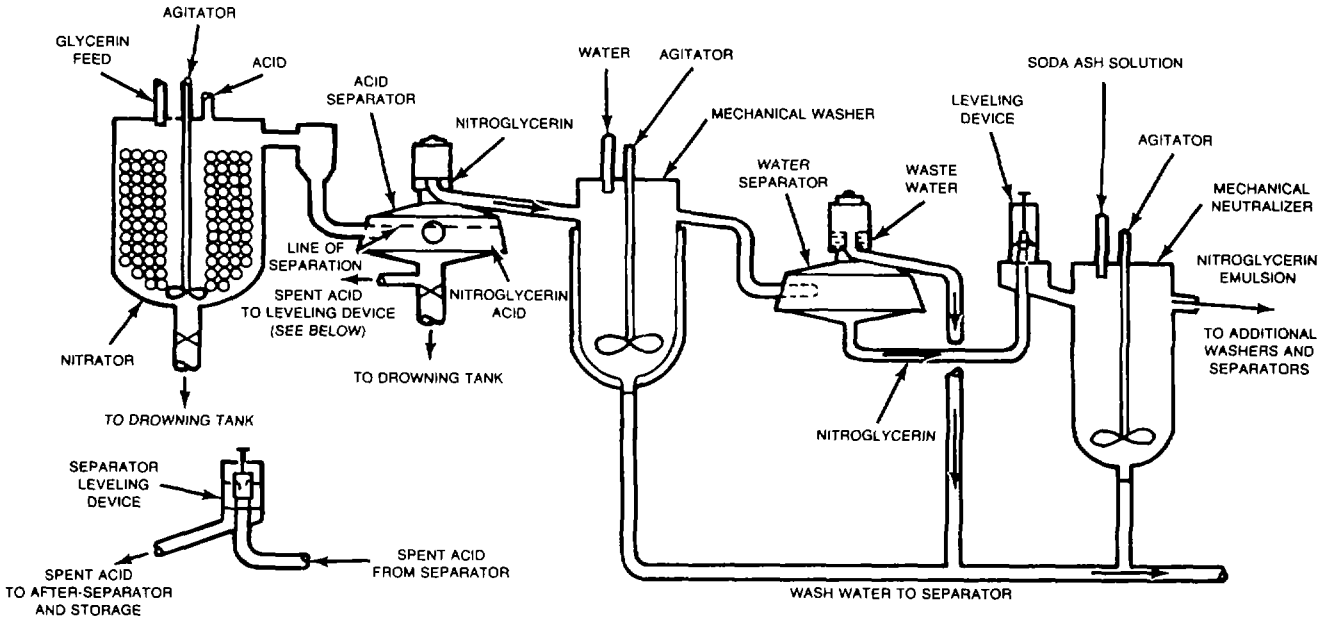


Figure 8-7. Schmid-Meissner continuous method for manufacturing nitroglycerin.

2 The Biazzi process (figure 8-8) is similar to the Schmid-Meissner, but is considered to be safer because of the smaller amount of nitroglycerin in the system at a given time. The nitrator is a small, cylindrical, stainless steel vessel provided with a bank of helical cooling coils. A high speed, shrouded, impeller-type agitator forces the nitrating acid up through the bank of coils and down through the cylindrical space in the center of the coils. The fresh, mixed acid and the material to be nitrated stored in large scale tanks or bins enter, in controlled ratio, at the top of the nitrator, striking the liquid at such a point in the vortex that the feed is immediately thrust beneath the surface and carried down through the central space formed by the coils. The mixture then spirals back, up and out, through the banks of cooling coils and a portion is carried off by the overflow pipe which leads to the separator. The flow of mixture past the coils is counter to the flow of cooling brine circulating through the coils. Because of this arrangement which permits rapid reaction through rapid heat absorption, the mixed acid can be stronger than that used in the Schmid-Meissner process. The cooling coils, agitator, and cover of the nitrator are mounted as a unit separate from the cylindrical body, which can be lowered hydraulically for inspection. The Biazzi acid separator is a stainless steel vessel of the shape shown in the figure. The emulsified mixture of nitrated product and spent acid enters tangentially through the side about midway up and imparts a slight centrifugal action to the upper layer of liquid in the separator. This action helps to break the emulsion and to prevent local overheating. The spent acid flows continuously from the bottom of the separator through a draw off valve, controlled by an adjustable collar, which can be raised or lowered by means of a micro screw attachment. After leaving the first separator, the acid is passed through an after-separator from which some of the nitrated product is recovered. The spent acid leaving the after-separator is usually diluted with water to dissolve traces of dissolved nitrated product. The separated, nitrated product is continuously drawn off from the first separator into a stainless steel wash tank equipped with a cylindrical baffle and an impeller-type agitator. Water is continuously added to the washer and the mixture overflows into a second separator. The nitrated product is drawn from the bottom of the separator and is conducted to the second washer where some soda wash solution is added with agitation. If a high purity nitrated product is required, such as for nitroglycerin used in propellants, the emulsion from the second washer, together with some soda ash solution, is conducted through a battery of three or four washers in which wash waters are running countercurrent to the movement of nitroglycerin. From there the emulsion passes through a series of separators arranged in cascade and is collected in a storage tank. In cases of overheating, the nitrator and the first separator can be emptied quickly into a drowning tank which is generally filled with water but can be filled with sulfuric acid. The Biazzi process is also used in the manufacture of DEGN and other aromatic and alphatic nitrocompounds. Only one nitrator is required for mononitration but for higher degrees of nitration more nitrators are added in series. Such nitrations usually employ the spent fortified acid from the higher nitration as the mixed acid for the next lower nitration.

3 The Swedish Nobel Aktiebolaget process for nitrating glycerin consists of an injector nitrator and a centrifugal separator for separating nitroglycerin from spent acid. The mixed acid used in this process is a mixture of about 1.7 parts spent acid and one part conventional, 50 percent nitric and 50 percent sulfuric acids, mixed acid. This mixture contains about 27 percent nitric acid and 10 percent water. Glycerin flow into the injector is controlled by the acid flow through the injector in the same manner that suction is produced by a water aspirator. Thus, if the acid flow is reduced by some equipment malfunctioning, the glycerin flow is automatically decreased. This process, unlike most of the others, operates at a high temperature, about 45° to 50°C. The glycerin or glycerin-glycol mixture is heated to 45° to 50°C before entering the injector. The mixed acid is cooled to 0°C. In the injector the heat of reaction maintains the fluid temperature at 45° to 50°C. Automatic controls give warning or shut down the operation if the temperature rises a few degrees above the normal range. The nitroglycerin acid emulsion enters a cooling system immediately after leaving the injector. The temperature of 45° to 50° is maintained for only about half a second. During the next 80 to 90 seconds the mixture is cooled to 15°C. In the following 30 seconds the nitroglycerin is separated from the spent acid. A continuous centrifugal separator separates nitroglycerin from the spent acid. The centrifuge operates at 3,200 rpm. For a unit with a capacity of 25,000 liters per hour the quantity of nitroglycerin in the separator bowl during operation is only 3.5 kilograms. The separated acid free nitroglycerin is emulsified immediately by a wash jet to form a nonexplosive mixture and is removed continuously from the separator house to the nitroglycerin wash-and-weigh house.

4 Another proposed method is very similar to the Nobel Aktiebolaget process where the reaction is carried out in a tube. The significant difference is that the mixed acid and glycerin are pumped and turbulent flow is maintained in the tube to ensure a complete, rapid reaction. The reactants are then cooled, separated, and washed.

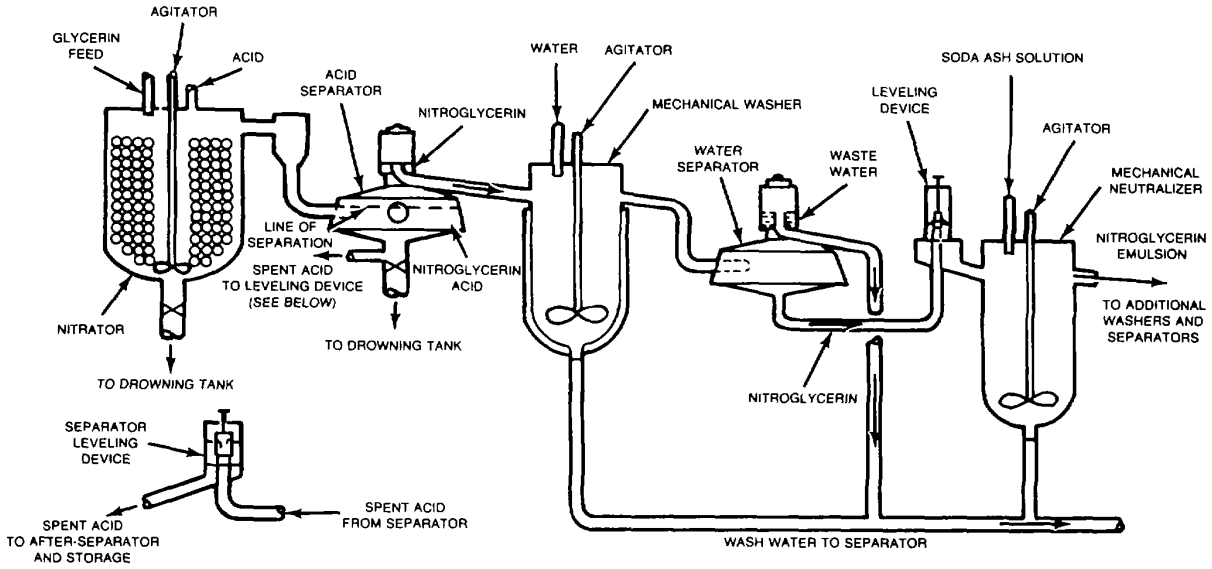


Figure 8-8. Biazzi continuous method for manufacturing nitroglycerin.

(8) There are two grades of nitroglycerin specified for military use. Type I uses grade B glycerin for manufacture. Type II uses partially polymerized glycerin. These two grades must comply with the following requirements:

	Type I	Type II
Moisture content, maximum	0.5 percent	0.5 percent
Acidity or alkalinity, maximum	0.002 percent	0.002 percent
Nitrogen content	18.40 percent, minimum	17.8 percent, minimum 17.9 percent, maximum
82.2°C, KI test, Minimum	10 minutes	10 minutes

The KI test does not measure stability but indicates the presence or absence of trace impurities not found in highly purified nitroglycerin.

(9) The great sensitivity of nitroglycerin is generally recognized. The pendulum friction test indicates nitroglycerin is very sensitive to friction. Impact test results vary with the instrument used, however, they all indicate nitroglycerin is very sensitive to impact. The Picatinny Arsenal impact test shows nitroglycerin is more sensitive than mercury fulminate. The results of impact tests have been found to depend on the area of the impacted nitroglycerin, the smoothness of the two surfaces involved, and the aeration of the nitroglycerin. The tests indicate a force of at least 1000 gram centimeters is necessary when using a five centimeter diameter weight but with a 2.5 centimeter diameter weight a greater force is required. Even the slightest dents in the anvil will greatly increase the sensitivity as measured by an impact test. Detonation is attributed to thermal ignition from compressed gas bubbles with the degree of compression being higher in the area of a dent. An increase in temperature increases sensitivity to impact markedly. Frozen nitroglycerin is much less sensitive than liquid and the liquid increases in sensitivity as the temperature rises. The most sensitive form, however, is when crystals are in contact with the liquid. Many accidents have occurred when frozen dynamite was jarred while being thawed. In general, unconfined bulk nitroglycerin is difficult to ignite by flame or heat, the ease of ignition improving as the nitroglycerin layer becomes thinner. Nitroglycerin may explode instead of igniting if large quantities are subjected to localized, sudden heating. If a very small quantity of the material is contained in a capillary glass tube and this is exposed to a flame, the nitroglycerin detonates with a loud report. When compared with similar values for other explosives, the five second explosion temperature test value of nitroglycerin, 222°C, does not indicate the observed sensitivity to initiation by heat. At 50° to 60°C nitroglycerin liquid or the liquid saturated in filter paper does not explode or ignite from a 13 kilovolt spark from an eight micro farad capacitor. In gap sensitivity tests, blends of 15 percent nitroglycerin and 85 percent inert salts were packed in two identical 30 to 32 millimeter diameter tubes and placed end to end on dry sand a definite distance apart. Detonation of one tube resulted in detonation of the other at maximum gaps for these salts of: NH_4CI at 25 centimeters, NaCI at 11 centimeters, $NaHCO_3$ at 10 centimeters. Diammonium sulfate,

diammonium carbonate, chalk, or talc did not transmit the detonation even at zero gap. The particle size of the salts is important. For NaCI the optimum size is 0.10 to 0.12 millimeter in greatest dimension. Nitroglycerin is initiated to detonation by a black powder squib, but not uniformly so. No data are available in connection with the sensitivity of nitroglycerin to initiation by initial detonating agents. However, the fact that 40 percent straight dynamite can be detonated by lead styphnate indicates a high degree of sensitivity, since lead styphnate will not detonate pressed PETN and this is very sensitive to initiation.

(10) Pure nitroglycerin is too sensitive to be transported by common carrier. A mixture of 70 parts of nitroglycerin and 30 parts of acetone by weight is relatively insensitive and sometimes is transported by wagon or truck. Such a mixture can be detonated by a No. 8 blasting cap. Modified Bureau of Mines impact tests of various mixtures gave the sensitivity values shown by table 8-3.

Table 8-3. Impact Sensitivity of Nitroglycerin-Acetone Mixtures

Composition, percent		Impact test centimeters
Nitroglycerin	Acetone	
100	0	16
90	10	23
80	20	41
75	25	60
73	27	64
70	30	100 +

The nitroglycerin in such a mixture can be separated from the acetone by precipitating the nitroglycerin by addition of an excess of water or by evaporating the acetone with a current of air. An emulsion of 87 percent nitroglycerin and 13 percent water that has been stabilized with methyl cellulose also has been found to be sufficiently insensitive to permit safe handling. This mixture is not detonated by a blasting cap.

(11) The detonation velocity of nitroglycerin varies according to the method of initiation. When properly initiated, the normal rate of detonation at a density of 1.60 grams per cubic centimeter is given as 7,700 meters per second. When improperly initiated, the rate can be as low as 1,500 to 2,000 meters per second. The rate of detonation also varies according to the state of the nitroglycerin. In a 22 millimeter inner diameter glass tube with a 7,000 meters per second picric acid fuse, detonation velocities of 9,150 meters per second, 0 meters per second, and 1,165 meters per second were obtained for the stabile, labile, and liquid forms, respectively. Use of a 20 gram tetryl booster gave 9,100 meters per second for the labile form. Use of 10 to 15 grams of the stabile form as a booster gave 8,750 meters per second for the liquid form. Tests indicate that the brisance of the stabile form is much higher than either the labile or liquid form. The Trauzl lead block compression test indicates nitroglycerin is 115 percent as brisant as TNT while the sand test indicates a value of 120 percent. The temperature of explosion is given as 4,577°C for the decomposition as shown:

$$NG \longrightarrow 3CO_2 + 2.5H_2O + 1.5_2N + 0.5O_2$$

and a resultant pressure of 10,000 atmospheres. Trauzl lead block test results of 390 cubic centimeters, 518 cubic centimeters, and 560 cubic centimeters were obtained for the stabile, liquid, and labile forms, respectively. The Trauzl lead block test value for nitroglycerin is greater than that for any other military explosive. This is in agreement with the correspondingly high heat of explosion value. The ballistic pendulum test values indicate RDX and PETN to be more powerful than nitroglycerin. This can be explained by the fact that nitroglycerin has a ratio of combined oxygen to oxygen required for complete combustion of 105.9 percent, while RDX and PETN have corresponding ratios of 66.7 and 85.7 percent, respectively. In the Trauzl test, the samples are not in contact with air, while in the ballistic pendulum test, air surrounds the sample when placed in the explosion chamber. This would tend to increase the test value for explosives that are less than oxygen-balanced but have no effect on the test value for nitroglycerin.

(12) Nitroglycerin is quite stable at temperatures less than 50°C, as shown by storage tests over a period of years. At higher temperatures, the rate of decomposition increases rapidly, and 100°C vacuum stability test data show that at that temperature nitroglycerin is the least stable of the standard military explosives of the noninitiating type. Nitroglycerin does not cause significant corrosion of metals. This is attributed to the low solubility in water, the stability, and the neutrality of nitroglycerin. Rust markedly increases the decomposition of nitroglycerin, as indicated by 100°C vacuum stability tests. The presence of more than a trace of free acid renders nitroglycerin quite unstable; decomposition with the appearance of red fumes takes place within a few days.

e. *Nitrostarch (NS).*

(1) Nitrostarch is a mixture of nitrates obtained by nitrating starch. The general formula for starch is $C_6H_{10}O_5$. The structure of starch is the same as for nitrocellulose, as shown in figure 8-3, with the exception that the polymer chains are spiral rather than straight. The starch molecule consists of approximately 1,000 anhydroglucose units. The nitration of starch involves replacement of the hydrogen in the three hydroxyl (OH) groups in the anhydroglucose units with NO_2 groups. A representative formula for the nitrated starch may be written as $C_6H_7(OH)x(ONO_2)y$ where $x+y=3$. The NO_2 groups are distributed randomly along the entire length of the starch molecule, so x and y should be regarded as averages over the entire length of the chain. The following empirical formula can be employed to obtain y as a function of the nitrogen content N:

$$y=162N/(1400-45N)$$

The appearance of nitrostarch is practically the same as the unnitrated starting material. Nitrostarch's solubility characteristics are determined by nitrogen content. With a nitrogen content below 8 percent, nitrostarch is scarcely soluble in a mixture of ether and alcohol. If the nitrogen content is between 8 percent and 12.8 percent, the solubility is complete but with a nitrogen content of over 12.8 percent, nitrostarch is only partially dissolved. For a nitrogen content of 6.4 percent, the solubility is 8.4 percent and for a nitrogen content of 13.1 percent the solubility is 78 percent. In acetone the solubility is complete for a nitrogen content of more than 6.4 percent. In ethyl alcohol the solubility is complete if the nitrogen content is between 10 and 11.5 percent. From a chemical viewpoint, nitrostarch may be considered to be another form of nitrocellulose with the same nitrogen content. Decomposition can be accomplished with sulfuric acid in the presence of mercury. Therefore nitrogen content can be measured by an nitrometer. When dissolved in nitric acid and allowed to stand, nitrostarch is decomposed. As with nitrocellulose, aqueous alkali solutions cause saponification. Nitrostarch has a wide variety of gelatinizing agents and is used rather than nitrocellulose in explosive compositions chiefly as a substitute for nitroglycerin. These compositions have the major advantage of being nonfreezing and not subject to the desensitization that accompanies the freezing of nitroglycerin explosives. Nitrostarch explosives have been used as successfully in the Antarctic and Arctic regions as in temperate climates. There is no standard grade of nitrostarch used for military purposes, but there is a specified commercial grade having a nitrogen content from 12.8 to 13.3 percent.

(2) The methods of production and stabilization of nitrostarch are considered trade secrets, so details are scarce. The starch used is produced from corn or cassava and can be obtained from potatoes. This is purified to some extent by washing with a dilute sodium hydroxide or ammonia solution to remove fats and pectic acid and then washing with water. The starch is then dried so that the moisture content is less than 0.5 percent. Nitrostarch can be prepared by dissolving starch in an excess of nitric acid and pouring this solution into an excess of sulfuric acid to precipitate the nitrostarch as an amorphous powder. This method is uneconomical and hard to control and consequently, not used commercially. The usual preparation methods employ mixed acids. The nitrogen content of the nitrostarch depends on the composition of the mixed acid and on the mixed acid to starch ratio. A ratio of 4 parts mixed acid to 1 part starch is used in one manufacturing process. The starch is added to the mixed acid in a nitrator, the temperature not exceeding 38° to 40°C. The composition of the mixed acid varies with the degree of nitration desired; an acid for nitration to 12.75 percent nitrogen contains 38 percent nitric acid and 62 percent sulfuric acid. After nitration is complete, the contents of the nitrator are drowned in cold water and the nitrostarch caught on a filter. Nitrostarch is purified by washing with cold water, with the addition of ammonia during the preliminary washing, until all traces of free acid are removed. After separation on a filter or in a centrifugal wringer, the nitrostarch is dried on trays in a dry house, heated to 35° to 40°C. The drying operation is the most dangerous of those involved in the manufacture of nitrostarch because the dry material is sensitive to ignition by spark and burns with great violence. Nitrostarch can also be prepared via nitration with nitric and phosphoric acids N_2O_5 dissolved in nitric acid; N_2O_5 dissolved in chloroform; or nitric acid with P_2O_5

(3) Nitrostarch is slightly less sensitive to impact than guncotton, or about 280 percent as sensitive as TNT. The explosion temperature test value of nitrostarch, 217°C, is essentially the same as that for nitrocellulose, 230°C.

(4) The brisance and power of nitrostarch are similar to those of nitrocellulose of comparable nitrogen content. The detonation velocity depends on the nitrogen content. The range for properly detonated nitrostarch is from 1,000 meters per second at 8.9 percent to 6,190 meters per second at 13.4 percent.

(5) Heat tests at 120° and 134.5°C indicate nitrostarch is less stable than nitrocellulose; at ordinary temperatures, the two appear to be of similar stability as judged by long term storage tests.

f. *Pentaerythritol Tetranitrate (PETN).*

(1) PETN is also known as 2,2-bis [(nitrooxy) methyl]-1,3-propanediol dinitrate; penthrite; or nitropenta and may be referred to as TEN. The compound (figure 8-9) is a white solid with a molecular weight of 316.2. PETN has two polymorphs: one with a tetragonal crystalline structure and the other with an orthorhombic crystalline structure. The phase change between the two polymorphs occurs at 130°C. The tetragonal crystals have a density of 1.778 grams per cubic centimeter and the orthorhombic crystals have a density of 1.716 grams per cubic centimeter. Normal manufacturing yields tetragonal crystals. The unit cell dimensions of the tetragonal crystals are a=9.38 Angstroms, b=9.38 Angstroms, and c =6.71 Angstroms. The dimensions for the orthorhombic crystals are a=13.29 Angstroms, b = 13.49 Angstroms, c = 6.83 Angstroms. There are two molecules per cell in the tetragonal form and four molecules per cell in the orthorhombic form. The interatomic distances have been determined as 1.50 Angstroms for the C-C bonds, 1.37 Angstroms for the C-O bonds, 1.36 Angstroms for O-N bonds, and 1.27 Angstroms for N-O bonds. PETN melts at 141.3°C. The boiling point is 160°C under a pressure of 2 torr; 180°C under a pressure of 50 torr. Under atmospheric pressure at temperatures above 21 0°C, PETN decomposes rapidly and in some cases detonates. The vapor pressure of solid PETN can be found by the empirical equation:

$$\log p = 16.73 - 7750/T$$

where p is the vapor pressure in millimeters of mercury and T is in degrees Kelvin. The vapor pressure of liquid PETN can be determined by the relationship:

$$\log p = 14.44 - 6352/T$$

The standard heat of formation of PETN is given as 128.7 kilocalories per mole. The heat of detonation is 1.65 kilocalories per gram for liquid water and 1.51 kilocalories per gram for gaseous water. The specific heat is given by the equation 0.239 +0.008° for T in the range of 32°C to 127°C. Two equations are given for the specific heat of PETN as a function of temperature:

$$C = 0.257 + (5.21 \times 10^{-4})T \text{ for } T \leq 140°C$$

and $C = 0.239 + (8.0 \times 10^{-4})T$

for $32°C < T < 127°C$

where C is in units of calories per gram per degree centigrade. The heat of combustion is 618.7 kilocalories per mole and the heat of formation is-110.34 kilocalories per mole. Table 8-4 lists the packing density as a function of loading pressure.

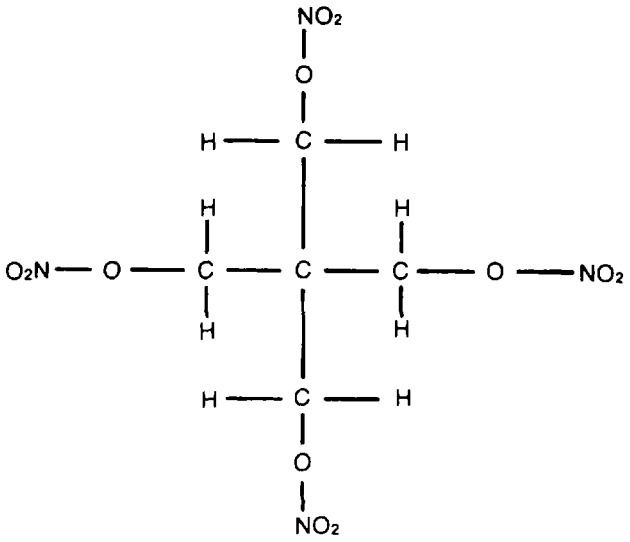


Figure 8-9. Structural formula of PETN.

Table 8-4. Packing Density

Pressure kilograms per square centimeter	Density grams per cubic centimeter
351	1.575
703	1.638
1,406	1.710
2,109	1.725
2,812	1.740

PETN crystals have a scratch hardness of slightly less than 2 on the Mohs scale. PETN is practically insoluble in water; at 25°C and 96°C the solubility is only 0.0043 and 0.018 grams per 100 grams of water, respectively. Table 8-5 lists the solubility of PETN in acetone-water mixtures.

Table 8-5. Solubility of PETN in Acetone Water Mixtures

Amount of PETN, in grams, dissolved in 100 grams of solvent	Acetone concentration				
	55%	70%	80%	90%	92%
	Temperature of solution, °C				
1	41				
2	52				
2.5	-	24.5			
4	62				
5	-	41.5	22		
10	-	54.5	38.5	15	10
15	-	62	48	24.5	20.5
17.5	-	65			
20	-	-	54	34.5	29
25	-	-	59	41.5	34
30	-	-	63	46.5	40.5
35	-	-		51.5	45
40	-	-	-	55	50
45	-	-	-	58.5	54
50	-	-	-	61.5	57.5
55	-	-	-		-60.5
60	-	-	-		62.5

PETN forms eutectic mixtures with a number of compounds as shown in table 8-6.

Table 8-6. PETN Eutectics

Composition	Melting point (C°)
1.5 percent PETN with 98.5 percent nitroglycerin	12.3
20 percent PETN with 80 percent m-dinitrobenzene	82.4
10 percent PETN with 90 percent 2,4-dinitrotoluene	67.3
13 percent PETN with 87 percent trinitrotoluene	76.1
30 percent PETN with 70 percent tetryl	111.3
20 percent PETN with 80 percent mannitol hexanitrate	101.3

(2) PETN is decomposed much more slowly by a boiling 2.5 percent solution of sodium hydroxide than nitrocellulose. Several hours are required for complete decomposition. At 50°C a solution of sodium sulfide decomposes PETN slowly, but decomposition proceeds rapidly in a boiling solution of ferrous chloride. PETN does not reduce Fehling's solution even on boiling. Hydrolysis of PETN takes place in water about 100°C; at 125°C under pressure the reaction proceeds quite quickly. Addition of 0.1 percent nitric acid enhances the hydrolysis. The main product of hydrolysis is pentaerythritol dinitrate. At temperatures up to about 50°C, dry PETN does not react with copper, brass, aluminum, magnesium, magnesium-aluminum alloys, stainless steel, mild steel, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc. Wet PETN does not react with stainless steel, and aluminum is affected only slightly after long periods of storage. However copper, brass, magnesium, magnesium-aluminum alloys, mild steel, mild steel coated with acid-proof black paint, and mild steel plated with cadmium, copper, nickel or zinc are affected. PETN is used in the explosive core of industrial detonating fuses, in the charge of commercial blasting caps, and as the entire explosive charge in exploding bridge wire detonators. PETN is also used in certain plastic bound explosives and in a mixture with TNT called pentolite.

(3) While PETN can be manufactured by treating pentaerythritol with nitric acid and adding concentrated sulfuric acid to complete the separation of the PETN, manufacture in the United States has been with nitric acid alone:

$$C(CH_2OH)_4 + 4HNO_3 \longrightarrow C(CH_2NO_3)_4 + 4H_2O$$

This is accomplished by adding approximately 75 pounds of pentaerythritol to 350 pounds of 98 percent nitric acid in a nitrator, and stirring and cooling the acid continuously. The pentaerythritol is added at a rate that, with an initial acid temperature of 18°C, the temperature increases to and is maintained at 22° to 23°C. Stirring and cooling are continued for 20 minutes after addition of the pentaerythritol is complete. The acid solution then is added, with agitation, to about 850 pounds of cold water in a drowning tank. The precipitated PETN is caught on a glass-cloth filter and washed with water. The precipitate is then mixed with 1,300 gallons of cold water containing 2 pounds of sodium carbonate and separated from the slurry by refiltering. After being washed again with water, the PETN is dissolved in 440 pounds of 98 percent acetone heated to 50°C and containing 14 ounces of ammonium bicarbonate. The solution is filtered and the PETN precipitated by the addition of cold water to the acetone solution. The precipitated solid is caught on a filter and washed with water to remove acetone. The water wet material is considered the final product. Drying is done at the point of use. The yield of PETN by this process is approximately 93 percent of the theoretical. The spent acid resulting from the drowning operation contains approximately 20 percent nitric acid. This is recovered and concentrated. The mother liquor, resulting from the precipitation of PETN, contains approximately 25 percent acetone, which also is recovered. The purity of PETN produced by this process depends upon that of the pentaerythritol nitrated. Ordinarily, the pentaerythritol used for nitration contains 2 or 3 percent of dipentaerythritol and a small amount of tripentaerythritol:

$(HOH_2C)_3C.CH_2O.CH_2.C(CH_2OH)_3$ and
$(HOH_2C)_3C.CH_2O.CH_2C(CH_2OH)_2.CH_2O.CH_2C(CH_2OH)_3$.

PETN produced on a large scale contains corresponding amounts of the hexanitrate and octanitrate of these compounds, respectively.

(4) One grade of PETN is used for military purposes and this complies with the following requirements:

Color: White or light buff.
Moisture[1]: Minimum, 40 percent.
Melting point: 141°±1°C.
Nitrogen content: Minimum, 17.50 percent.
Acetone insoluble[1]: Maximum, 0.10 percent
Insoluble particles[2]: None
Acidity or alkalinity[2]: Maximum, 0.01 percent
120°C vacuum stability test: Maximum, 5 milliliters of gas from 2.3 grams in 20 hours.

Granulation:

Through sieve No.		Class A	Class B	Class C	Class D
30	Minimum	-	-	95	100
80	Minimum	100	-	-	-
100	Maximum	-	-	-	20
100	Minimum	85	96	-	5
140	Maximum	55	-	-	-
200	Maximum	30	80	30	-
200	Minimum	-	65	-	-

[1]Not applicable to class C PETN used in coprecipitated pentolite.
[2]Not applicable to class C PETN.

Class A PETN is used in detonating fuses and boosters; class B is used in priming compositions; class C is used in the manufacture of pentolite; and class D is used in blasting caps and detonators. Pure PETN has a nitrogen content of 17.72 percent and a melting point of 141.3°C. The military grade is approximately 99 percent pure. The insoluble particles requirement is important because of the sensitivity of PETN and the known effect of gritty material in increasing sensitivity. The acidity or alkalinity requirement is important since the presence of as little as 0.01 percent of either has been found to accelerate the deterioration of PETN markedly. The granulation requirements are those found optimum for specific uses of PETN.

(5) PETN is not as sensitive to impact as nitroglycerin or nitrocellulose, but is slightly more sensitive than RDX and distinctly more so than tetryl. Experiments using a five kilogram weight dropped one meter onto a 15 milligram sample of polycrystallin PETN show the physical changes that occur before initiation. The layer of PETN compresses to about 0.1 millimeter thick. After about 10 microseconds, lateral spreading stops and jetting occurs at 150 meters per second. The initially opaque layer of PETN becomes gradually translucent in an additional 10 to 15 microseconds and completely transparent in 15 to 20 microseconds. The transparency and rapid mobility of the PETN is associated with surface fusion and then melting of the entire sample. About 25 microseconds after the lateral spreading has stopped, the jetting velocity has increased to 300 meters per second and five microseconds after that several hot spots develop simultaneously. The exact mechanism of how the hot spots form is controversial and no generally satisfactory explanation has been put forward. The hot spots are points where deflagration has started. Initially, the deflagration proceeds at several tenths of a meter per second. The products of gaseous combustion raise the pressure of the reaction region and accelerate the rate of deflagration. At the same time, the products of hot combustion penetrate into unreacted regions to produce new ignition sites and a further pressure increase, accelerating deflagration even more. At about 5 to 15 millimeters from the point of initiation, the velocity of the flame front has increased to several hundred meters per second. The flame front drives a compression wave into the unreacted material. When this compression wave attains a velocity of about 700 to 800 meters per second, there is a sharp increase in the propagation velocity to about 1000 meters per second. Depending on the condition of the explosive, this low velocity detonation can propagate over considerable distances or can go over into a normal detonation whose propagation velocity is determined by the density and dimensions of the PETN layer. One condition that can cause acceleration of the detonation velocity to normal is going from a region of 90 percent crystal density to one of 80 percent crystal density. Initiation by friction and electrical spark proceeds like initiation by impact after the formation of the hot spots. The maximum nonignition spark voltage and nonignition energy for PETN with a particle size of 2.6 microns is 12000 volts and 0.036 joules, respectively, at 500 micro farads capacitance and a spark gap of 0.005 inches. The energy required to detonate PETN 50 percent of the time is 0.19 and 0.36 joules for brass electrodes with lead foil coatings of 3 and 10 mils, respectively. For a steel electrode, the energy required is 0.1 and 0.41 joules with lead foil coatings of 1 and 10 mils, respectively. The physical condition of the explosive appears to have some influence on the amount of energy required for initiation. The discharge energy required increases with PETN particle size, packing density, water content, circuit inductance, and a decrease in ambient temperature. PETN is not particularly sensitive to electrostatic spark. The electrostatic sensitivity parameters should not be confused with the initiation of PETN by an exploding bridge. The exploding bridge is a wire through which a large current is passed, causing the wire to burst. There is an optimum length for each wire material and a minimum critical volume of explosive that must be detonated to cause initiation. Other factors that enhance the ability of the bridge to detonate PETN are: high power input to increase temperature and pressure, a sustained electrical energy input just after the wire bursts to provide simultaneous electrical and chemical energy contributions during the critical growth to detonation period, and use of wire materials with low boiling points and heats of vaporization for greater heat transfer. Attempts to initiate PETN by normal light have been generally unsuccessful although a few instances of some deflagration have occurred with very intense light. Lasers can be used to initiate PETN. The energy required for initiation increases with increased packing density. PETN five millimeters thick with a density of one gram per cubic centimeter can be detonated by a neodymium glass laser with an output at 10600 Angstroms when the beam is focused to produce a power density in excess of 0.08 megawatts per square millimeter. The delay in producing a steady detonation under these conditions is 1.5 to 2.0 microseconds. The delay can be reduced to under 0.5 microseconds if the PETN is coated with a 1000 Angstrom thick layer of aluminum which has been deposited on the sample, and the laser radiation is from 0.5 to 4.2 joules for 25 nanoseconds. Initiation appears to be a thermal process. The laser energy is absorbed rapidly in a thin layer of explosive which produces a shock wave that causes the initiation of the entire sample.

(6) Gap tests indicate the shock sensitivity of PETN increases as packing density increases and as particle size increases. Gap test results are shown in table 8-8.

Table 8-8. Gap Test Results for PETN

	Density	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.775	0.3	6.03
	1.576	11.5	14.38
	1.355	27.9	13.56
LANL small scale gap test	1.757 (pressed)	0.7	5.21
LANL large scale gap test	0.81 (raw)	54.2	69.4

Increasing the pressure of an inert gas such as carbon dioxide, nitrogen, or a Nobel gas in the interstices of a PETN pressing decreases shock sensitivity. Increasing the pressure of oxygen increases shock sensitivity. In cast PETN and PETN that has been pressed to 90 percent of the crystal density, substantial reactions take place well behind the shock front that enters the charge and proceeds through the explosive. Stable detonation occurs when the compression waves produced by this reaction catch up with the initial shock front. PETN is less sensitive to friction than RDX and more sensitive than nitroglycerin, as judged by the pendulum friction test. Explosion temperature test values indicate PETN to be as sensitive to heat as nitroglycerin or nitrocellulose. However, the minimum temperature required for the explosion of PETN, 215°C, is greater than that required for the explosion of nitroglycerin, 210°C, and nitrocellulose, 175°C. PETN is more sensitive to initiation than nitrocellulose, RDX, or tetryl, as judged by the sand test. This is shown, also, by the fact that PETN with 35 percent of water present can be detonated by a No. 6 electric blasting cap, whereas RDX fails to explode if more than 14 percent of water is present. PETN is one of the most sensitive of the standardized military explosives.

(7) As measured by the sand test, PETN is between 129 and 141 percent as brisant as TNT. Plate dent tests indicate PETN is 127 percent as brisant as TNT and the lead block compression test indicates a brisance of between 130 and 137 percent of TNT. Table 8-9 lists the detonation velocity of PETN at various packing densities determined experimentally with the confinement indicated.

Table 8-9. Detonation Velocity Versus Density

Density (g/cc)	Detonation velocity (m/sec)	Density (g/cc)	Detonation velocity (m/sec)
1.773	8,300*	1.27	6,660†
1.765	8,280†	1.26	6,760†
1.765	8,240*	1.09	5,830†
1.763	8,270*	0.55	3,850*
1.762	8,250*	0.436	3,400*
1.762	8,260*	0.241	2,810*
1.51	7,440†	0.201	2,730*
1.51	7,490†	0.185	2,670*

*Unconfined rate stick
†Cylinder test

The following equations, which are in agreement with the data in the table, specify the detonation velocity in kilometers per second as a function of density, p, for the range indicated.

$D=2.14+2.84p$ $\quad p < 0.37$
$D=3.19+3.7(p-0.37)$ $\quad 0.37 < p < 1.65$
$D=7.92+3.05(p-1.65)$ $\quad p > 1.65$

The diameter of a PETN charge has little effect on the velocity of detonation. The charge diameter below which no detonation can take place (the critical diameter) is only 0.9 millimeters for PETN at a density of one gram per cubic centimeter with 0.025 to 0.1 millimeter particles. The critical diameter becomes smaller as the density of the charge is increased. Since confinement effects parallel the diameter effects, the detonation velocity of PETN is not greatly affected by confinement for any particular charge size. This is also indicated by table 8-9. Detonation, or Chapman-Jouguet, pressure is shown as a function of packing density in table 8-10.

Table 8-10. PETN Detonation Pressures Versus Density

Density grams per cubic centimeter	Dimensions of PETN: Diameter x length Centimeters (inches) Shock Electric Effect Measurements	Detonation pressure (kbar)
1.764	5 x 1.3 (2 x 0.5)	338
1.763	2.5 x 1.3 (1 x 0.5)	333
1.763	2.5 x 2.5 (1 x 1)	340
1.763	5 x 1.3 (2 x 0.5)	338
1.763	5 x 2.5 (2 x 1)	340
1.762	5 x 2.5 (2 x 1)	339
1.758	2.5 x 2.5 (1 x 1)	333
1.71	2.5 x 2.5 (1 x 1)	309
1.70	2.5 x 2.5 (1 x 1)	307
1.69	2.5 x 2.5 (1 x 1)	304
1.60	2.5 x 2.5 (1 x 1)	266
1.59	2.5 x 2.5 (1 x 1)	259
1.53	2.5 x 2.5 (1 x 1)	225
1.46	2.5 x 2.5 (1 x 1)	198
1.45	2.5 x 2.5 (1 x 1)	208
1.44	2.5 x 2.5 (1 x 1)	199
1.38	2.5 x 2.5 (1 x 1)	173
1.23	2.5 x 2.5 (1 x 1)	138
0.99	2.5 x 1.3 (1 x 0.5)	87
0.95	2.5 x 1.3 (1 x 0.5)	85
0.93	2.5 x 2.5 (1 x 1)	77
0.93	2.5 x 3.8 (1 x 1.5)	72
0.89	2.5 x 2.5 (1 x 1)	71
0.88	2.5 x 2.5 (1 x 1)	68
	Optical (Smear Camera) Measurements	
0.48	3.8 x 2.5 (1.5 x 1)	24
0.30	3.8 x 1.3 (1.5 x 0.5)	24
0.29	3.8 x 2.5 (1.5 x 1)	15
0.27	3.8 x 1.3 (1.5 x 0.5)	5
	Quartz Crystal Measurements	
0.25	4.5 x 2.5 (1.75 x 1)	8
0.25	4.5 x 2.5 (1.75 x 1)	7
0.25	4.5 x 3.8 (1.75 x 1.5)	6

The ballistic mortar test indicates PETN is 137 to 145 percent as powerful as TNT. The Trauzl test indicates PETN is 161 to 189 percent as powerful as TNT. PETN is ranked with RDX and nitroglycerin as the most potent of military explosives.

(8) The products obtained upon detonation of PETN depend on the density of the explosive. The four equations listed in subparagraphs (a) through (d) are valid at the density given. The subscript s refers to soot. The soot is produced in the Chapman-Jouguet region by the reactions:

$$CO + H_2 \longrightarrow C_s + H_2O$$
$$2CO \longrightarrow C_s + CO_2$$

(a) For PETN with density of 1.77 grams per cubic centimeter:

$$C_5H_8N_4O_{12} \longrightarrow 3.95CO_2 + 0.096CO + 0.95C_s + 4.00H_2O + 2N_2 + 477.4 \text{ kcal/mole}$$

(b) For PETN with density of 1.67 grams per cubic centimeter:

$$C_5H_8N_4O_{12} \longrightarrow 3.89CO_2 + 0.22CO + 0.88C_s + 4.00H_2O + 2N_2 + 474.2 \text{ kcal/mole}$$

(c) For PETN with density of 1.2 grams per cubic centimeter:

$$C_5H_8N_4O_{12} \longrightarrow 3.04CO_2 + 1.96CO + 3.96H_2O + 0.025H_2 + 2N_2 + 436.3 \text{ kcal/mole}$$

(d) For PETN with density of 1.0 grams per cubic centimeter:

$$C_5H_8N_4O_{12} \longrightarrow 3.04CO_2 + 1.96CO + 3.94H_2O + 0.050H_2 + 1.99N_2 + 0.02NO + 436.3 \text{ kcal/mole}$$

and minor amounts of NH_3, H, OH and CH_4.

(9) Vacuum stability tests at 100° and 120°C show PETN to be more stable than nitrocellulose or nitroglycerin at elevated temperatures but distinctly less stable than RDX, tetryl, or TNT. PETN is quite stable at 100°C and can withstand heating at this temperature for 100 hours without significant deterioration. In the LLNL reactivity test 0.10 to 0.14 cubic centimeters of gas are evolved per .25 grams of sample. Figure 8-10 shows the percentage of PETN decomposition as a function of time and temperature for temperatures over 140°C. The curves were obtained by heating a sample to the indicated temperature for the indicated time then analyzing the remaining PETN. The following six reactions, which take place simultaneously, show the mechanism of thermal decomposition:

1 $RCH_2ONO_2 \longrightarrow RCH_2O + NO_2$
2 $NO_2 + RCH_2O \longrightarrow RCH_2ONO_2$
3 $RCH_2O \longrightarrow$ intermediate decomposition products (IDP) such as H_2CO
4 $IDP + NO_2 \longrightarrow NO + N_2O + N_2 + CO + CO_2 + H_2O$
5 $RCH_2ONO_2 + H_2O \xrightarrow{HNO_3} RCH_2OH + HONO$
6 $H_2O + 3NO_2 \longrightarrow 2HNO_3 + NO$

PETN is shown as RCH_2ONO_2. Storage at 65°C for 20 months does not cause instability or undue acidity; and after 24 months only slightly excessive acidity develops. Figure 8-11 shows the DTA curve and figure 8-12 shows the TGA curve for PETN. When 0.01 percent of free acid or alkali is present, storage for only 15 months at 65°C results in rapid acceleration of the rate of decomposition. Since RDX, tetryl, and TNT are even more resistant to storage at 65°C, PETN is not as suitable for storage and use under tropical conditions.

g. *Triethylene Glycoldinitrate (TEGN).*

(1) This explosive is also referred to as TEGDN. The compound (figure 8-13) is a light yellow, oily liquid with a nitrogen content of 11.67 percent, a molecular weight of 240.20, and an oxygen balance to CO_2 of -66.6 percent. The melting point of the solid is -19°C. Other characteristics of the liquid are: refractive index, 1.4540; viscosity at 20°C, 13.2 centipoises; vapor pressure at 25°C, less than 0.001 torr; volatility at 60°C, 40 milligrams per square centimeter per hour; and density, 1.335 grams per cubic centimeter. At constant pressure, TEGN's heat of combustion is 3428 calories per gram, heat of explosion is 725 kilocalories per kilogram, and heat of formation is -603.7 kilocalories per kilogram. TEGN is very soluble in acetone, ether, and a solution of 2 parts ether and 1 part ethanol. TEGN is soluble in carbon disulfide and slowly soluble in water. The primary use of TEGN is as a gelatinizing agent for nitrocellulose in propellants, but TEGN can also be used as a component in a liquid explosive, a plasticizer in the fabrication of flexible explosive sheets, and as a plasticizer in pytrotechnic flares.

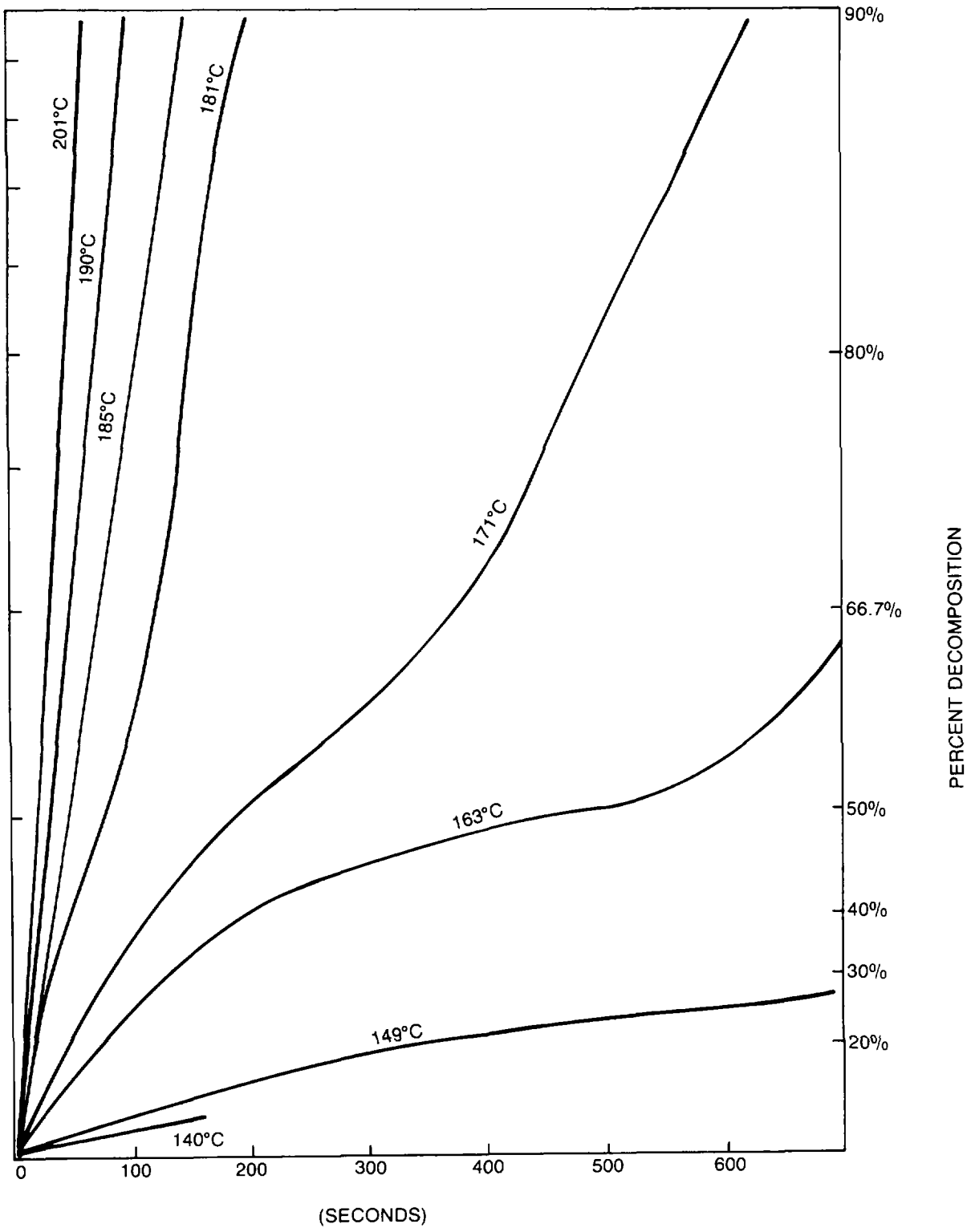


Figure 8-10. Thermal decomposition of PETN.

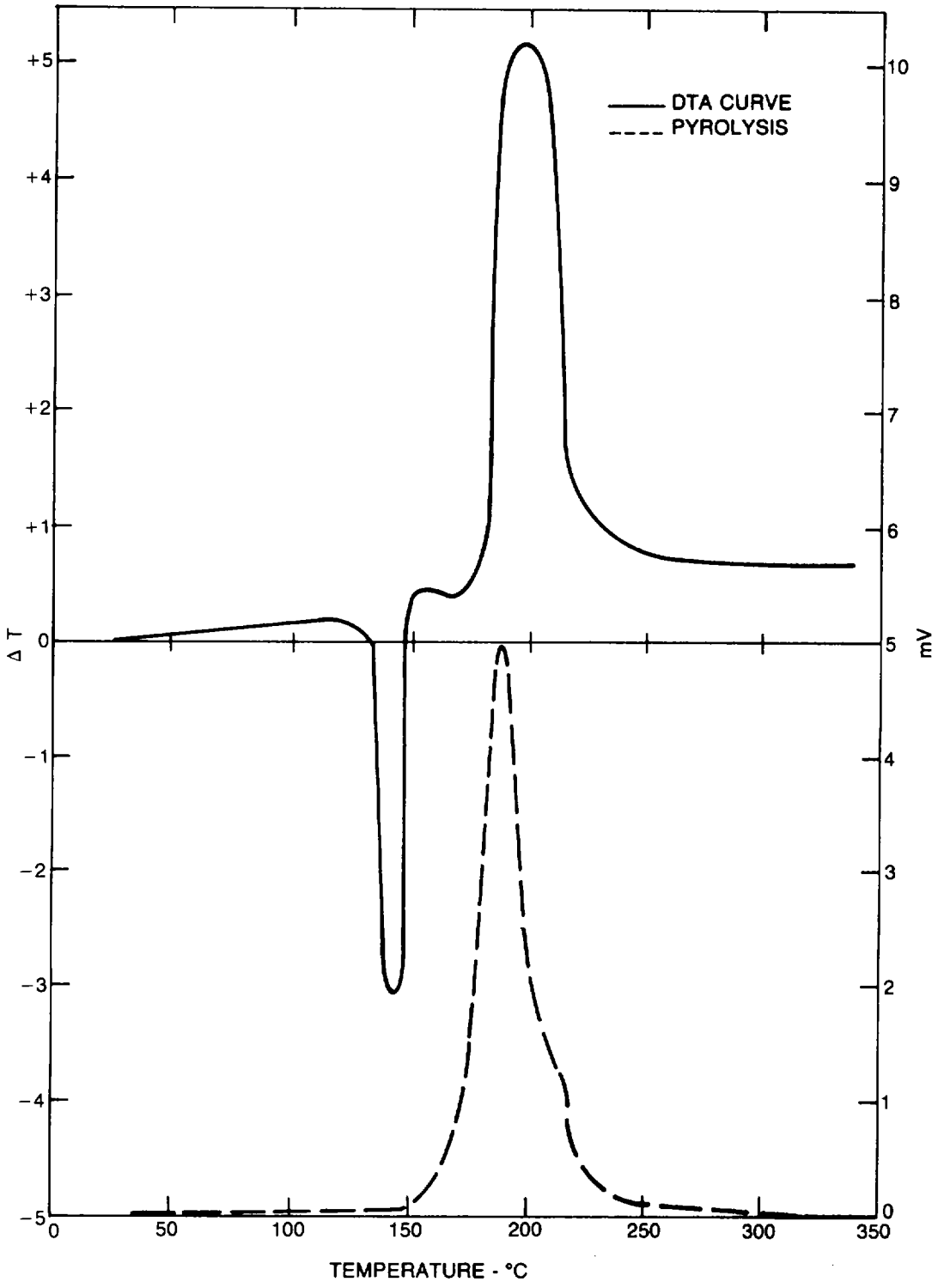


Figure 8-11. DTA curve for PETN.

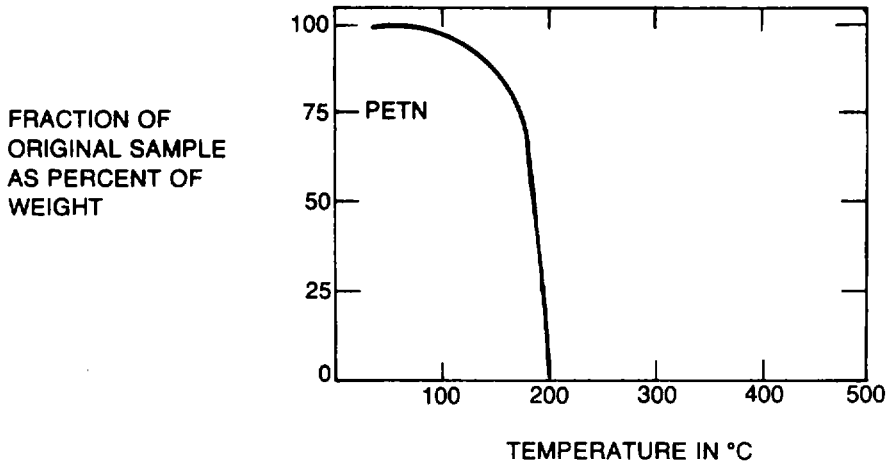


Figure 8-12. TGA curve for PETN.

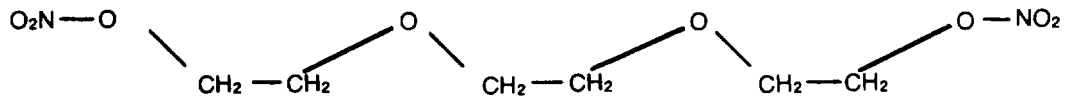


Figure 8-13. Structural formula for TEGN.

(2) TEGN is prepared by the nitration of triethylene glycol. The laboratory procedure for the production of TEGN is given here. The actual manufacturing procedure is by the Biazzi process, discussed under nitroglycerin. The triethylene glycol is purified by fractional distillation under vacuum in an 18 inch Vigeaux fractionating column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C and a take-off temperature of approximately 120°C. The purified triethylene glycol is carefully stirred into a mixed acid that consists of 65 percent nitric acid, 30 percent sulfuric acid, and 5 percent water that is maintained at 0 ± 5°C. The mixture is stirred and held at 0 ± 5°C for 30 additional minutes and then drowned by pouring over a large quantity of ice. The TEGN is extracted three times with ether and the combined extract is water washed until the pH is about four, then shaken with an excess solution of sodium bicarbonate, and further washed with a 1 percent sodium bicarbonate solution until the washings are colorless. The ether solution is then water washed until the pH is seven. The solution is then carefully separated from the excess water, treated with chemically pure calcium chloride to remove the dissolved water, and filtered. The ether is removed by bubbling with dry air. The yield is 1.34 grams of TEGN per gram of triethylene glycol, 84 percent of theoretical. The nitrogen content of different batches can vary from 11.60 to 11.69 percent with 11.67 percent the calculated value. A modification that allows continuous rather than batch nitration is to dissolve the triethylene glycol and mixed acid separately in dichloromonofluoromethane, $CHFCl_2$ or freon 21, and then mix the two solutions. A sufficient quantity of $CHFCl_2$ must be used to maintain the temperature at 11°C and to ensure a safe degree of dilution of the solution. The dispersant is evaporated and the TEGN is recovered. The yield of this process is 74 percent.

(3) TEGN is unaffected in the pendulum friction test with the metal and fiber shoe. The Bureau of Mines impact test indicates a sensitivity of over 100 centimeters and the Picatinny Arsenal impact test indicates 109 centimeters. The five second explosion temperature test value is 225°C.

(4) The 1 00°C heat test, with losses of 1.8 percent and 1.6 percent for the first and second 48 hour periods, respectively, indicates TEGN is much more stable than nitroglycerin but considerably less stable than all other standard explosives. No explosions occur in the 100 hour observation period. The vacuum stability test results, 45 milliliters of gas in 40 hours at 100°C and 0.80 to 0.99 milliliters of gas in eight hours at 120°C, indicate that TEGN is more stable than PETN, slightly less stable than RDX, and much less stable than TNT.

(5) TEGN is insensitive to detonation. No detonation occurs in samples placed in relatively light steel tubing with a diameter of 3.175 centimeters at a density of 1.33 grams per cubic centimeter. When heavily confined, the detonation velocity is less than 2,000 meters per second, or 30 percent of TNT. The 200 gram sand test indicates a brisance of 30.6 percent of TNT, with 14.7 grams of sand crushed. TEGN's deflagration point is 195°C.

(6) TEGN is extremely toxic and should be considered a potent poison when absorbed through the skin or ingested. Tests with rabbits indicate 21 millimoles per kilogram of body weight causes death in two to three weeks when absorbed through the skin. A level of intraperitonal exposure of 995 milligrams per kilogram of body weight causes death within 24 hours to 50 percent of the rats treated. TEGN, when selectively applied, can also inhibit the nerve functions in rats.

h. *1,1,1 Trimethylolethane Trinitrate (TMETN).*

(1) This explosive is also known as metriol trinitrate and is sometimes referred to as MTN. The compound (figure 8-14) is a slightly turbid, viscous oil with a nitrogen content of 16.41 percent and a molecular weight of 255.15. TMETN has a melting point of -3°C and an apparent boiling point of 182°C, but this is merely the temperature at which decomposition becomes vigorous enough to resemble boiling. Other properties of the liquid are a density of 1.47 grams per cubic centimeter at 22°C and a refractive index of 1.4752 at 25°C. TMETN is practically insoluble in water. Less than 0.015 grams dissolved per 100 grams of water at up to 60°C. TMETN is soluble in alcohol and many other organic solvents. At 60°C TMETN's volatility is 24 milligrams per square centimeter. The heat of formation is 422 calories per gram at constant volume and 446 calories per gram at constant pressure. The heat of combustion is 2,642 calories per gram at constant volume with the water being liquid. In an acid bath, TMETN is hydrolyzed to the extent of 0.018 percent in 10 days at 220°C and 0.115 percent in 5 days at 60°C. TMETN can be used as a flash and erosion reducing additive in propellants and an ingredient of commercial explosives. TMETN alone does not gelatinize nitrocellulose unless the temperature is raised to 100°C, which would be dangerous. But if mixed with only 8 percent of metriol triacetate, gelatinization takes place at 80°C. When TMETN is mixed with nitroglycerin, the mechanical properties of double-base cast propellants are improved. Combinations with triethylene glycol dinitrate are used as plasticizers for nitrocellulose.

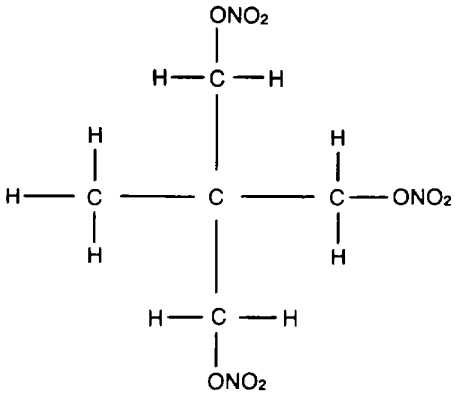


Figure 8-14. Structural formula for TMETN.

(2) One method for the manufacture of TMETN is to feed 50 kilograms of finely powdered metriol into a nitrator provided with cooling coils and an agitator. The nitrator contains 175 kilograms of mixed acid that consists of 65 percent nitric acid and 35 percent sulfuric acid. The nitration time is about 20 minutes at 20°C after which the contents of the nitrator are allowed to set for 15 minutes. The TMETN separates from the spent acid and is decanted and then washed at 40°C with an aqueous solution of soda and then with water. The yield is almost 100 kilograms of TM ETN with a nitrogen content of 16.32 to 16.36 percent.

(3) The Bureau of Mines impact apparatus indicates TMETN is as sensitive as nitroglycerin, with a drop height of four centimeters for a two kilogram weight. The five second explosion temperature test value is 235°C and TMETN detonates with both the metal and fiber shoe in the pendulum friction test.

(4) TMETN is 91 percent as brisant as TNT with 43.7 grams of sand crushed in the sand test. The Trauzl test and ballistic mortar test indicate TMETN to be 140 percent and 136 percent, respectively, as powerful as TNT.

(5) The stability of TMETN is not very satisfactory as indicated by the vacuum stability and heat tests. In the 100°C heat test, a 2.5 percent weight loss is reported in the first 48 hours and 1.8 percent in the second 48 hours. No explosions occur in the first 100 hours. In the 100°C vacuum stability test, 1.9 cubic centimeters of gas are evolved in the first 40 hours. At 25°C TMETN is hygroscopic to the extent of 0.07 percent with 90 percent relative humidity and 0.14 percent at 100 percent relative humidity.

8-3. Nitramines. Compounds in this class are prepared by N-type nitration in which a nitro group is attached to a nitrogen atom of the compound being nitrated.

a. *Cyclotetramethylenetetranitramine (HMX).*

(1) HMX is also known as: octahydro-1,3,5,7-tetranitro-1 ,3,5,7-tetrazocine; 1,3,5,7-tetranitro-1 ,3,5,7-tetrazacyclooctane; cyclotetramethylene tetranitramine; or octogen. HMX (figure 8-15) is a white, crystalline solid with a nitrogen content of 37.84 percent, a theoretical maximum density of 1.905 grams per cubic centimeter, a nominal density of 1.89 grams per cubic centimeter, a melting point of 285°C, and a molecular weight of 296.17. There are four polymorphs of HMX: an alpha, beta, gamma, and delta form. Each polymorph has a range of stability and there are differences among them in physical properties such as density, solubility, and refractive index. The most common polymorph is the beta form. The term HMX without an alpha, gamma or delta qualifier refers to the beta form throughout the rest of this text. The crystalline structure of beta HMX is monoclinic with a density of 1.903 grams per cubic centimeter. The unit cell dimensions are a=6.54 Angstroms, b=11.05 Angstroms, and c=8.70 Angstroms. Beta HMX is stable to about 102°C to 104.5°C, when the crystalline structure is converted to the alpha form. The crystals of the alpha form are orthorhombic with a density of 1.82 grams per cubic centimeter. The unit cell dimensions are a=15.14 Angstroms, b =23.89 Angstroms, c = 5.91 Angstroms. At approximately 160°C to 164°C the meta stable gamma form exists. The crystals of the gamma form are monoclinic with a density of 1.76 grams per cubic centimeter. The unit cell dimensions are a=10.95 Angstroms, b =7.93 Angstroms, and c = 14.61 Angstroms. Above the 160°C to 164°C range to the melting point, the delta form exists. The crystals of the delta form are hexagonal with a density of 1.80 grams per cubic centimeter. The unit cell dimensions are a=7.71 Angstroms and b=32.55 Angstroms. The polymorphs may also be prepared by precipitation from solution under various conditions. The beta form is precipitated from a solution of HMX in acetic acid, acetone, nitric acid, or nitrometrane with very slow cooling. The alpha form is precipitated from the same solution with more rapid cooling and the gamma form is precipitated with even more rapid cooling. The delta form is crystallized from solution such as acetic acid or betachloroethyl phosphate, in which HMX is only slightly soluble. Very rapid chilling of the solution is required. This is usually accomplished by pouring small quantities of the solution over ice. Military grade HMX consists only of the beta polymorph. HMX is insoluble in water, but is soluble in the solvents listed in table 8-11 to the degree shown.

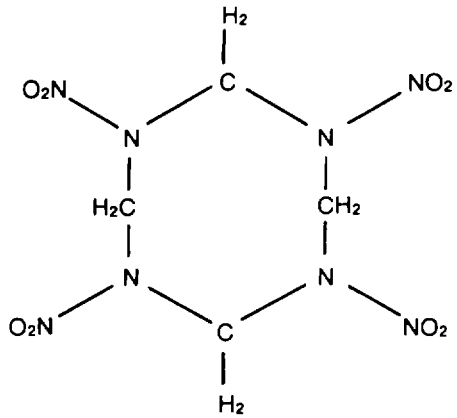


Figure 8-15. Structural formula for HMX.

Table 8-11. Solubility of HMX

Solvent	Grams of HMX dissolved per 100 grams of solution	Temperature °C
Dimethylformamide	4.4	25
Nitrobenzene	0.129	25
1,2-Dichlorethane	0.125	70
Acetic acid	0.0375	25
Acetone	0.96	25
Acetonitrile	1.98	25
Cyclohexanone	2.11	25
Ethylacetate	0.02	25
Ethylbromide	0.02	25
Methylethylketone	0.46	25
Nitroethane	0.172	25
Nitromethane	0.778	25
Triethylphosphate	1.75	25

Table 8-12 lists the solubility of HMX by volume for various solvents.

Table 8-12. Solubility of HMX by Volume

Solvent	Grams of HMX dissolved per 100 milliliters of solution
Gamma-butyrolactone	21.0
Cyclopentanone	1.3
Cyclohexanone	5.2
Acetone	2.2
Acetonitrile	2.0
Nitromethane	1.1
Nitroethane	0.03
Methylisobutylketone	1.8

HMX will also dissolve to the extent of 0.003 grams, 0.002 grams, and 0.144 grams in 100 milliliters of chloroform, carbon tetrachloride, and dioxane, respectively. Carbon disulfide will not dissolve HMX. Table 8-13 lists specific heat values for HMX at various temperatures.

Table 8-13. Specific Heat of HMX

Temperature °C	Calories per gram per degree centigrade
-75	0.153
0	0.228
25	0.248
50	0.266
75	0.282
85	0.288
90	0.290
100	0.295
125	0.307
150	0.315

HMX has a hardness of 2.3 on the Moh's scale, a heat of combustion of 660.7 to 667.4 kilocalories per mole, a heat of formation of 11.3 to 17.93 kilocalories per mole, a heat of detonation of 1.62 kilocalories per gram with liquid water and 7.48 kilocalories per gram with gaseous water. The vapor pressure of HMX in torr is given by the following equations for the temperature ranges indicated:

$\log p = 16.18 - 9154/T(\mathrm{K})$ for 97.6°C < T < 129.3°C
$\log p = 15.17 - 8596/T(\mathrm{K})$ for 188°C < T < 213°C

HMX and RDX are chemically very similar except that HMX is not easily decomposed by alkaline hydroxide. Concentrated sulfuric acid liberates a little more than one third of nitric acid with HMX while with RDX a little more than two thirds is liberated. HMX is used as an explosive charge when desensitized, as a booster charge in admixtures with TNT called octols, and as an oxidizer in solid rocket and gun propellants.

(2) Two grades of HMX are used for military applications. Both grades consist of only the beta polymorph and must meet the following requirements:

	Grade A	Grade B
Purity, minimum:	93 percent	98 percent
RDX content, maximum:	7 percent	2 percent
Melting point, minimum:	277°C	277°C
Acetone insoluble material, maximum:	0.05 percent	0.05 percent
Inorganic insoluble material, maximum:	0.03 percent	0.03 percent
Insoluble particles on US standard 40 sieve:	none	none
US standard 60 sieve:	5	5
Acidity	0.02 percent	0.02 percent

In addition the HMX must meet the following granulation requirements:

Through US Standard	Class 1 Percent	Class 2 Percent	Class 3 Percent	Class 4 Percent	Class 5 Percent	Class 6 Percent
8				100		
12			99 min	85 min		99 min
35				25 ± 15		
50	90 ± 6	100	40 ± 15			90 min
100	50 ± 10		20 ± 10	15 max		65 ± 15
120		90 min				
200	20 ± 6		10 + 10			30 ± 15
325	8 ± 5	75 min			98 min	15 ± 10

(3) To manufacture HMX, a solution of 785 parts glacial acetic acid, 13 parts acetic anhydride, and 17 parts paraformaldehyde is maintained at a temperature of 44°C ± 1°C. All part measurements in this discussion are by weight. The solution is held at that temperature throughout the subsequent steps of the process. Two more solutions are prepared. One consists of 101 parts hexamine and 165 parts acetic acid. The other is prepared by dissolving 840 parts ammonium nitrate in 900 parts of 99 percent or stronger nitric acid. Over a 15 minute period with constant stirring, the hexamine-acetic acid solution, 180 parts of the nitric acidammonium nitrate solution, and 320 parts acetic anhydride are added simultaneously, continuously, and equivalently. The mixture is aged for 15 minutes. In the second stage of the reaction, 320 parts of acetic anhydride and 271 parts of the nitric acid-ammonium nitrate solution are added proportionately, then 160 parts of acetic anhydride are added in bulk. The mixture is allowed to age for 60 minutes. Then 350 parts hot water are added and the solution is refluxed for 30 minutes. After cooling to 20°C by adding ice, the water insoluble precipitate is collected and washed with three portions of cold water. The yield of 200 parts HMX is 95 percent of the theoretical and the purity is higher than 90 percent. The product is alpha HMX which is converted to beta HMX by crystallization from boiling acetone, acetonitrile, or cyclohexanone, using equivalent parts of solid and solvent. The recrystallized HMX has a melting point of 278° to 279°C. The recrystallization process also removes any RDX that was formed during manufacturing.

(4) HMX has similar sensitivity to impact and friction as RDX. The Bureau of Mines impact apparatus with two kilogram weight measures 32 centimeters for a 20 milligram sample. In the pendulum friction test, HMX explodes with the steel shoe but is unaffected by the fiber shoe. Table 8-14 shows the gap test results for HMX.

Table 8-14. Gap Test Results for HMX

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.814	4.7	8.71
	1.517	20.3	11.28
LANL small scale gap test	1.840 (pressed)	3.2	3.43
	1.790 (pressed)	5.8	4.27
	1.20 (coarse)	36.8	8.53
	0.7 (fine crystals)	63	6.45
LANL large scale gap test	1.07	43.7	70.7

The minimum charge of lead azide required for detonation to obtain maximum brisance is 0.30 grams. Explosion temperature test values are 306°C in 10 seconds, 327°C in five seconds, and 380°C in 0.1 second. When HMX is under a compression of 93,082 kilopascals (13,500 pounds per square inch), the explosive can be reliably detonated by a Q-switched laser operating at 6,943 Angstroms. As measured in a differential thermalgraph analysis study, the auto ignition temperature of HMX is 234°C. In the spark sensitivity test with a brass electrode and a sample size of 66.9 milligrams, the energy required for a 50 percent probability of explosion for lead foil thicknesses of 3 and 10 mils is 0.2 joules and 1.03 joules respectively. For a steel electrode, the energy required is 0.12 joules and 0.87 joules for lead foil thicknesses of 1 and 10 mils, respectively.

(5) The sand test indicates HMX is 125 percent as brisant as TNT or about 96 percent as brisant as RDX. The ballistic pendulum test indicates 170 percent of TNT, the ballistic mortar test indicates 150 percent, and the Trauzl test indicates a power of 159 to 165 percent of TNT. The detonation velocity of HMX at a density of 1.89 grams per cubic centimeter is 9,110 meters per second. The following critical diameters were measured for HMX:

HMX/Wax, percent	Density grams per cubic centimeter	Critical diameters
90/10	1.10	$6.0 < dc < 7.0$
78/22	1.28	$7.0 < dc < 8.0$
70/30	1.42	$8.0 < dc < 9.0$

The diameters are given in millimeters. A gelled aqueous slurry of 30 percent HMX will detonate high order. At 25 percent HMX concentration detonation would be partially propagated and at 20 percent concentration the detonation would not propagate. Settled slurries propagate high order detonation at and above 10 percent HMX concentration. At the five percent level, the settled slurry will detonate about one third of the time.

(6) The 150°C vacuum stability test indicates HMX is comparable to TNT in stability, with test values of 0.6 and 2.5 milliliters of gas evolved. The 100°C heat test loss in the first 48 hours is 0.05 percent and in the second 48 hours 0.03 percent. No explosions occur in 100 hours. At 30°C and 95 percent relative humidity, HMX is nonhygroscopic. In the LLNL reactivity test, less than 0.01 cubic centimeters of gas are evolved. The DTA curve is shown in figure 8-16 and the TGA curve is shown in figure 8-17.

b. *Cyclotrimethylenetrinitramine (RDX).*

(1) This explosive is also known as: hexahydro-1,3,5-trinitro-1,3,5-triazine; 1,3,5-trinitro1,3,5-triazacyclohexane; cyclotrimethylene trinitramine; hexogen; cyclonite; or 1,3,5-trinitrotrimethylene-triamine. The compound (figure 8-18) is a white solid with a density of 1.806 grams per cubic centimeter, a nitrogen content of 37.84 percent, and a molecular weight of 222.13. RDX has orthorhombic crystals with a wide variety of habits; from needles when precipitated from HNO_3, to plates when precipitated from acetic acid, to a massive form when precipitated from nitroethane or acetone. The unit cell dimensions are a=13.18 Angstroms, b = 1 1.57 Angstroms, and c = 10.71 Angstroms, and there are eight molecules per cell unit. On the Moh's scale RDX has a scratch hardness of 2.5. Other properties of pure RDX include a specific heat as shown in table 8-15 and a heat of combustion at constant pressure of 2,307.2 calories per gram. The heat of formation value is + 14.71 kilocalories per mole. RDX has an extremely low volatility.

Table 8-15. Specific Heat of RDX

Temperature °C	Calories per gram per degree
20	0.298
40	0.331
60	0.360
88	0.384
100	0.406
120	0.427
140	0.446

Packing density as a function of pressure is shown in table 8-16.

Table 8-16. RDX Packing Density

Pressure kilopascals	Pressure pounds per square inch	Density grams per cubic centimeter
34,475	5,000	1.52
68,950	10,000	1.60
137,900	20,000	1.68
172,375	25,000	1.70
206,850	30,000	1.72

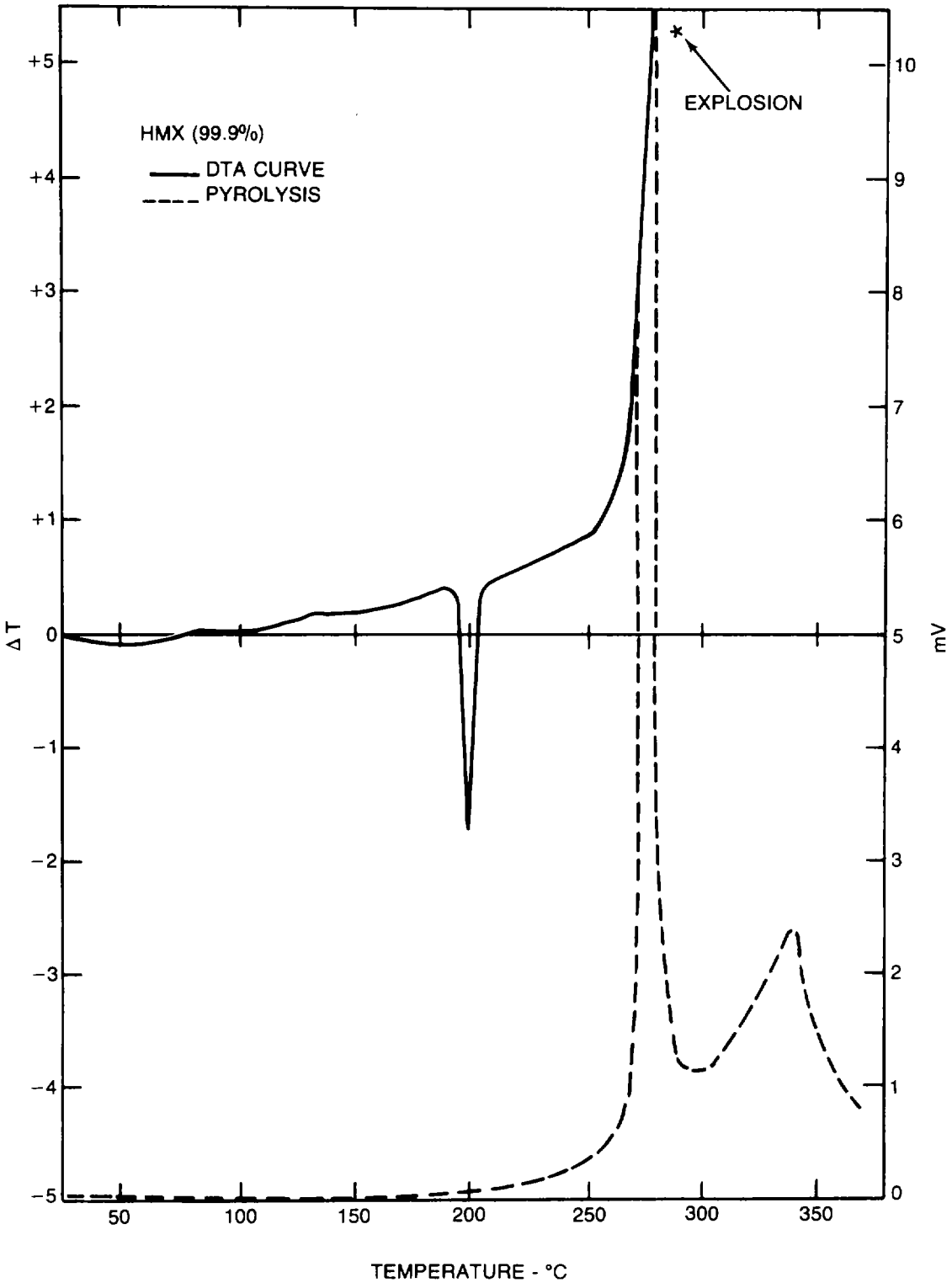


Figure 8-16. DTA curve for HMX.

RDX does not blend with or gelatinize nitrocellulose. With nitroglycerin, RDX forms an explosive plastic mass. Table 8-17 lists the solubility characteristics with TNT.

Table 8-17. RDX-TNT Solubility

Temperature °C	Grams of RDX dissolved per 100 grams of TNT
81	4.5
85	4.7
90	5.0
95	5.8
100	6.5
105	7.3
110	8.2

The eutectic mixture is 4.16 percent RDX at 79°C. Table 8-18 lists the solubility of RDX in various solvents. There is considerable divergence in the solubility data for RDX taken from different sources in the literature, probably due to the different methods and conditions used in making the determinations, the difference in purity, and the difference in physical state of the RDX tested.

Therefore, the values given in table 8-18 are only approximate. The coefficient of cubical expansion between 20°C and 100°C is 0.00025 cubic centimeters per gram per degree centigrade. RDX has a heat combustion of 501.8 to 507.3 kilocalories per mole at constant volume with liquid water. The heat of formation is 14.7 kilocalories per mole. The heat of detonation is 1.62 kilocalories per gram with liquid water and 1.48 kilocalories per gram with gaseous water. RDX detonates according to the empirically determined equation:

$$(CH_2NNO_2)_3 \longrightarrow 2CO + CO_2 + 2H_2O + H_2 + 3N_2$$

The temperature developed on explosion is 3380°C. There are two grades specified for RDX: types A and type B. Type A contains no HMX and type B has a constant impurity of from 8 to 12 percent HMX. Types A and B are produced by different manufacturing processes. Type A RDX melts between 202°C and 203°C; type B RDX melts between 192°C and 193°C. The vapor pressure of RDX is given by the equation:

$$\log p = 11.87 - 5850/T(\mathrm{K})$$

for $55.7°C < T < 97.7°C$

Pure RDX is used in press loaded projectiles but not in cast loaded projectiles because of extensive decomposition at the melting point. Cast loading is accomplished by blending RDX with a relatively low melting point substance. Compositions in which the RDX particles are coated with wax are called Composition A, in mixtures with TNT, Composition B, and blends with a nonexplosive plasticizer, Composition *C*. Straight RDX is used as a base charge in detonators and in some blasting caps, and as an oxidizer in specialized gun propellant.

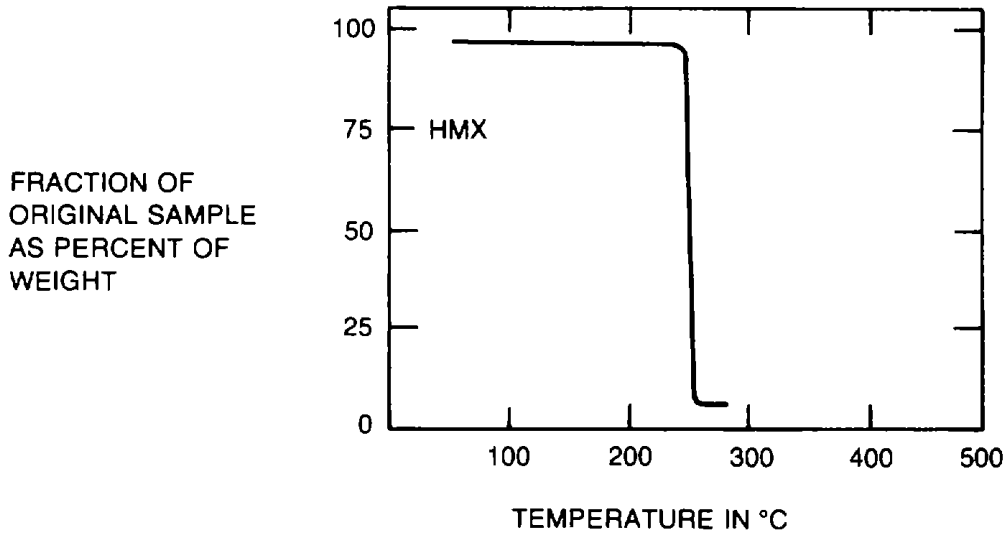


Figure 8-17. TGA curve for HMX.

Table 8-18. Solubility of RDX in Various Solvents

Solvent	Grams RDX per 100 grams of solution at						
	0°C	20°C	30°C	40°C	60°C	80°C	100°C
Acetic acid (50%)			0.12	-	0.50	1.25	-
Acetic acid (100%)	-	-	0.41	-	1.35	2.60	-
Acetic anhydride	-	4.0	4.80	6.0	9.30	-	-
Acetone	4.2	6.8	8.40	10.3	15.3	(at 58)	-
Acetonitrile	-	-	12.0	16.2	24.6	33.0	-
Alcohol, ethyl	0.04	0.10	-	0.24	0.60	1.20	-
Benzene	-	0.05	0.06	0.09	0.20	0.40	-
Carbon tetrachloride	0.0013	0.0022	0.0034	0.007	-	-	-
Chlorobenzene	0.20	0.33	0.44	0.56	-	-	-
Chloroform	-	0.015	-	-	-	-	-
Cyclohexanone	-	12.7 (at 25°)	-	-	-	-	25 (at 97°)
Cyclopentanone	-	-	11.5 (at 28°)	-	-	-	37 (at 90°)
Dimethylformamide	-	25.5	27.3	29.1	33.3	37.7	42.6
Ether, dethyl	-	0.055	0.075				
Beta-ethoxylethyl acetate	-	1.48	1.55	1.9	3.4		
Isoamyl alcohol	0.02	0.026	0.04	0.06	0.21	0.50	1.33
Methanol	0.14	0.235	0.325	0.48	1.06	-	-
Methyl acetate	-	2.95	3.30	4.10	6.05 (at 52°)	-	-
Toluene	0.016	0.02	0.025	0.05	0.125	0.295	0.64
Trichloroethylene	-	0.20	0.21	0.22	0.23 (at 52°)	-	-
Trinitrotoluene (TNT)	-	-	-	-	-	4.4	7.0
Water	-	0.005	-	0.025 (at 50°)	-	-	0.28

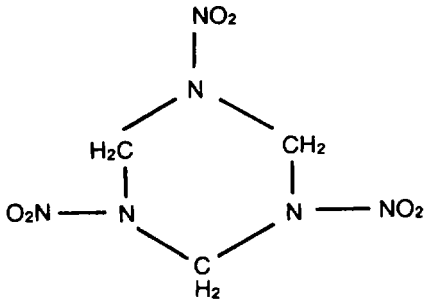


Figure 8-18. Structural formula for RDX.

(2) RDX is hydrolyzed slowly when treated with boiling, dilute sulfuric acid or sodium hydroxide according to the reaction:

$$C_3H_6N_6O_6+6H_2O \longrightarrow 3NH_3+3HCHO+3HNO_3$$

In sulfuric acid solution the nitric acid oxidizes the formaldehyde to formic acid while being reduced to nitrous acid. RDX dissolved in cold, concentrated sulfuric acid decomposes when the solution is allowed to stand. Reduction of RDX dissolved in hot phenol yields methylamine, nitrous acid, and hydrocyanic acid; but if solid RDX is suspended in 80 percent ethanol and reduced, both hydrolysis and reduction take place and the products are methylamine, nitrous acid, ammonia, and formaldehyde. With diphenylamine and sulfuric acid, RDX gives a strong blue color. RDX dissolves, without decomposing, in concentrations of up to 70 per-

cent nitric acid and may be recovered from solution by dilution with water. Hot or cold hydrochloric acid does not attack RDX. Complete decomposition can be obtained by heating RDX with equal parts of $Ca(OH)_2$ for four hours at 60°C. RDX decomposes slowly when heated at 60°C with a one tenth normal solution of sodium hydroxide for five hours, but rapidly when heated with a normal solution of sodium hydroxide. When RDX is placed in an alkaline solution, decomposition occurs. The products of that decomposition which have been isolated are: nitrogen gas, ammonia, nitrates, nitrites, formaldehyde, heramine, and organic acids such as formic. When mixed with oxides of heavy metals, such as iron or copper, RDX forms unstable compounds which may undergo decomposition and cause ignition of mixtures at temperatures as low as 100°C.

(3) Type A RDX is manufactured by the nitration of hexamethylenetetramine which is obtained by the reaction of formaldehyde and ammonia. The process is accomplished by slowly adding one part by weight of hexamethylenetetramine to 11 parts of 100 percent nitric acid, the temperature of which is maintained at 30°C or less while being stirred vigorously. The reaction proceeds according to the equation:

$$C_6H_{12}N_4 + 3HNO_3 \longrightarrow 3HCHO + NH_3 + (CH_2NNO_2)_3$$

The formaldehyde, HCHO, liberated by the reaction is oxidized by the nitric acid if the mixture is allowed to stand or is warmed. After being cooled to 0°C, the mixture is stirred for 20 minutes more and then drowned in ice water. As a result of the rupture and degradation of the hexamethylenetetramine molecule, numerous aliphatic and cyclic nitrocompounds are formed that are present in crude RDX. The crude RDX is caught on a filter and washed with water to remove most of the acid. Removal of all but a trace of acid is important and purification is accomplished by grinding the wet material then treating with boiling water or by recrystallizing from cyclohexanone or acetone. Production of type B RDX is based on the following reaction:

$$C_6H_{12}N_4 + 4HNO_3 + 2NH_4NO_3 + 6(CH_3CO)_2O \longrightarrow 2(CH_2NNO_2)_3 + 12CH_3COOH$$

The hexamethylenetetramine is nitrated to RDX by the nitric acid and, as indicated for the production of type A RDX, three moles of formaldehyde are produced. The formaldehyde reacts with the ammonium nitrate in the presence of the acetic anhydride, $(CH_3CO)_2O$, to form hexamethylenetetramine, which is nitrated by the nitric acid to form the second mole of RDX. The HMX impurity is not shown. The yield of the type B reaction is greater than for the reaction using nitric acid alone. Other methods for producing RDX include a process of nitrating hexamethylenetetramine by nitric acid in the presence of phosphorous pentoxide with a yield of 90 percent of theoretical. Nitration by some processes in the presence of ammonium salts such as $(NH_4)_2SO_4$ can increase yields. Yields of 65 percent, 80 percent and 91 percent were obtained using no ammonium salt, ammonium nitrate, and ammonium sulfate, respectively. Another possible method of manufacture uses nitrogen pentoxide dissolved in inert, nonaqueous solvents such as hydrocarbons or chlorinated hydrocarbons to nitrate hexamethylenetetramine. The equation for the reaction would be:

$$C_6H_{12}N_4 + 3N_2O_5 \longrightarrow (CH_2NNO_2)_3 + 3HCHO + 2N_2O_3$$

The yield for this method is claimed to be 89 percent. A proposed method for the production of type A RDX consists of oxidizing the compound 1,3,5-trinitroso1,3,5-triazacyclohexane, which is obtained from hexamethylenetetramine, HCL, and $NaNO_2$. Oxidization with hydrogen peroxide and nitric acid yields as an intermediate 1-nitroso-3,5 dinitroso-1,3,5 triazacyclohexane which is converted on further treatment with hydrogen peroxide and nitric acid into RDX having a melting point of 205°C.

(4) Type A and type B RDX are equally sensitive to impact, friction, heat, and initiation. This is due to the fact that HMX, the chief impurity in type B RDX, has sensitivity characteristics that are very similar to those of RDX. Impact tests indicate RDX is 300 percent as sensitive as TNT. Temperature has a marked effect on the sensitivity of RDX. Impact tests of a sample of type A RDX at 20°, 88°, and 105°C gave values of 9, 8, and 5 inches, respectively. Granulation also affects sensitivity; the height of fall increases with decreasing particle size. In pendulum friction tests, RDX explodes with the steel shoe but is unaffected by the fiber shoe. When rubbed in an unglazed porcelain mortar, partial deflagration occurs. RDX displays great sensitivity in the rifle bullet impact test, but the test samples partially deflagrate rather than detonate. RDX can be initiated by lead azide or mercury fulminate. Gap test results for RDX are shown in table 8-19.

Table 8-19. Gap Test Results for RDX

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.717	4.7	7.90
	1.546	14.2	12.01
	1.188	34.1	11.18
LANL small scale gap test	1.735 (hot-pressed)	4.1	4.8 - 5.6
	1.11 (bulk coarse)	38.7	8.86
	1.00 (bulk fine)	44.8	7.82
	0.7 (fine crystalline)	61	6.77

RDX is much less sensitive to an electric spark than tetryl, TNT, or PETN. Using a circuit with a capacitance of 0.0003 millifarads and a test sample of pulverized or crystalline RDX, no ignitions occur at 12,300 volts but local ignitions do occur at 14,950 volts. At elevated temperatures RDX either fumes off and ignites or deflagrates when unconfined. There are no explosions. Some elevated temperature test results are: at 255° to 260°C, five seconds; at 3160C, one second; at 405°C, 0.1 second. Held at 290°C RDX fumes. The flammability index is 278 versus 100 for TNT and 244 for tetryl. The presence of more than 14 percent moisture prevents detonation by a number 6 blasting cap.

(5) Reported sand test results indicate RDX is from 125 to 145 percent as brisant as TNT. Fragmentation tests, with 51 grams of explosive at a density of 1.50 loaded in a 40 millimeter shell, indicate a brisance of 141 percent of TNT. Plate cutting tests indicate RDX is 125 percent as brisant as TNT, while plate dent tests indicate 135 to 141 percent. The equation for detonation velocity is:

$$D = 2.56 + 3.47p$$

where D is in meters per second and p, the density, is in grams per cubic centimeter. Upon detonation, the pressure developed is 12,600 kilograms per square centimeter or 156 percent of TNT. The following were measured for RDX at the densities shown:

RDX/Wax percent	Density grams per cubic centimeter	Critical diameter
95/5	1.05	$4.0<d_c<5.0$
90/10	1.10	$4.0<d_c<5.0$
80/20	1.25	$3.8<d_c<5.0$
72/82	1.39	$3.8<d_c<5.0$

The diameters are given in millimeters. The volume of gas produced at 0°C and 760 millimeters of pressure is 908 liters per kilogram or 132 percent of TNT. Trauzl tests indicate RDX is 151 to 170 percent as powerful as TNT. However, tests against earthworks, masonry, and in underwater explosions indicate a power of close to 200 percent that of TNT. In one test a 25 kilogram charge of RDX in a shell produced a crater in packed earth 12.60 cubic meters in volume. The same amount of TNT under the same conditions produced a crater 6.75 cubic meters in volume. This indicates a power for RDX of 186.5 percent of TNT. The ballistic mortar test indicates a power of 150 to 161 percent that of TNT. These test results indicate RDX is the second most powerful military explosive.

(6) RDX is highly stable. In a one year surveillance test no decomposition occurred at either 65°C or 85°C. When heated for two months at 100°C no decomposition occurred. The 82.2 KI test results are 60 minutes. In the heat tests, the results were: at 75°C, .03 percent weight loss in 48 hours; at 100°C, 0.04 percent weight loss in the first 48 hours, no weight loss in the second 48 hours and no explosions after 100 hours; at 132°C no change occurred in eight hours of heating; and at 135°C there was no acid and no explosion in 300 minutes. A sample of five grams of RDX subjected to the vacuum stability test yielded the following results: in 40 hours at 120°C, 0.9 cubic centimeters of gas evolved and at 150°C, 2.5 cubic centimeters of gas evolved. A sample of five grams of type B RDX with a melting point of 192°C evolved 3.95 cubic centimeters of gas in 40 hours. In the LLNL reactivity test 0.02 to 0.025 cubic centimeters of gas were evolved. The DTA curve for RDX is shown in figure 8-19 and the TGA curve is shown in figure 8-20.

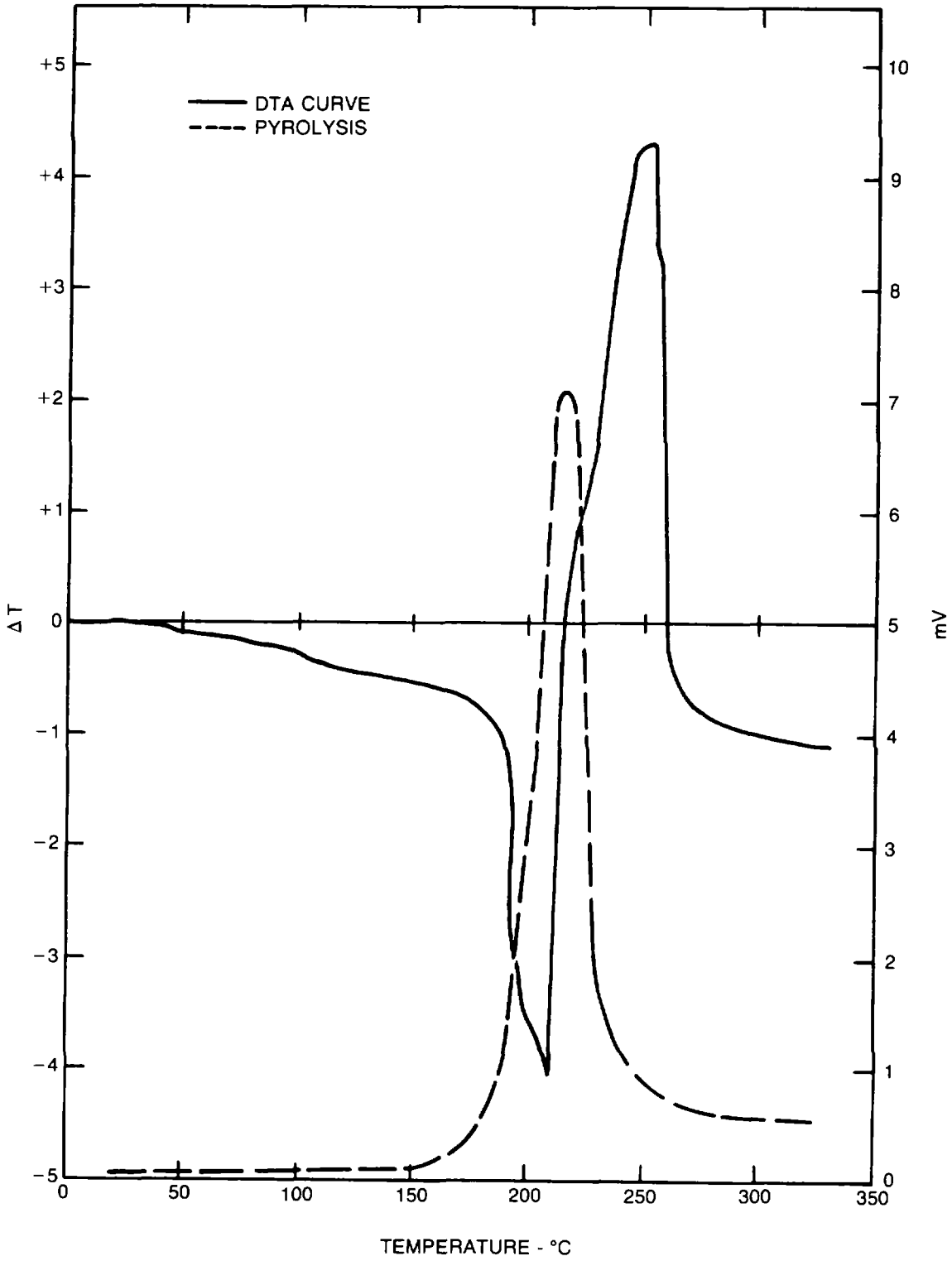


Figure 8-19. DTA curve for RDX.

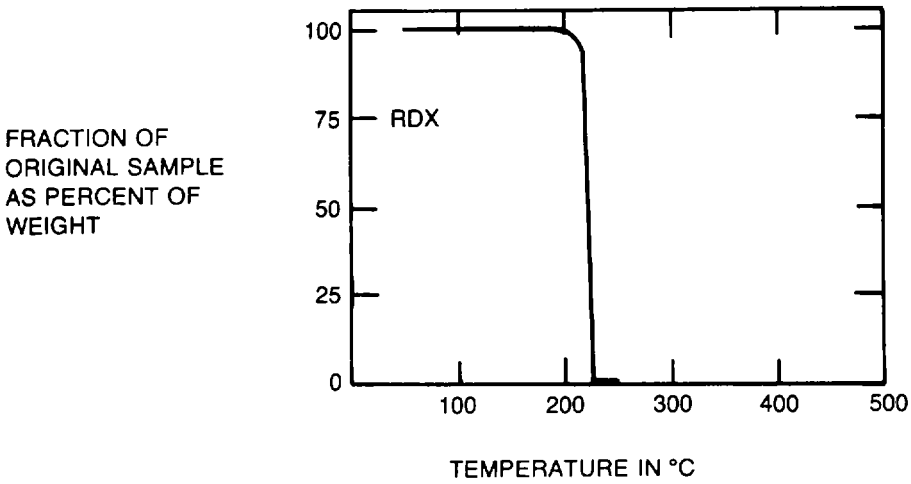


Figure 8-20. TGA curve for RDX.

(7) In the United States and England, RDX is stored wetted with water. In Germany and Japan it is stored dry. RDX does not cause corrosion of aluminum or stainless steel, even in the presence of moisture. Dry RDX causes no corrosion of and RDX with 0.5 percent moisture causes only slight corrosion of nickel or zinc. Dry or damp RDX causes very slight corrosion of copper, brass, mild steel, or cadmium.

(8) Table 8-20 lists the requirements for military grade RDX for the United States government.

Table 8-20. Types of RDX

Properties	Type A	Type B
Melting point, °C (min)	200.0	190.0
Acetone insoluble (max)	0.05	0.05
Inorganic insoluble (max)	0.03	0.03
Insoluble particles retained on US standard sieve No. 60, particles (max)	5	5
Acidity, percent (max)	0.05	0.02

Type A RDX is produced by the nitric acid process: type B is produced by the acetic anhydride process. Granulation requirements are listed in table 8-21.

Table 8-21. Granulation Requirements for RDX

Through US standard sieve No.	Class (% of material passing sieve)							
	A	B	C	D	E	F	G	H
8	-	-	-	100	-	-	-	-
12	-	-	99*	-	-	-	-	-
20	98	-	-	-	-	-	-	-
35	-	99	-	20	-	-	-	100
50	90	95	40	-	-	-	98	98*
60	-	-	-	-	-	99	-	-
80	-	-	-	-	-	97	-	-
100	60	65	20	-	-	-	90	90*
120	-	-	-	-	-	83	-	-
170	-	-	-	-	-	65	-	-
200	25	33	10	-	-	-	46	70
230	-	-	-	-	-	36	-	-
325	-	-	-	-	97*	22	-	50

*Minimum Percent

(9) The suggested uses of RDX based on class and granulation are as follows:

(a) Class A, for use in Composition A3, Composition B, Composition C4, and cyclotol

(b) Class B, for use in Composition A3 and Composition C4

(c) Class C, for use in the preparation of RDX booster and detonator pellets

(d) Class D, for use in cyclotols

(e) Class E, for use in Composition C4 and plastic bonded explosives (PBX's)

(f) Class F, for use in Composition B3

(g) Class G, for use in PBX's

(h) Class H, for use in Composition C4

c. Ethylenediamine Dinitrate (EDDN).

(1) This explosive is also designated EDD or EDAD. The compound (figure 8-21) is composed of white crystals with a specific gravity of 1.595 at 25/40, a nitrogen content of 30.10 percent, an oxygen balance to $C0_2$ of-25.8 percent, a melting point of 185° to 187°C, and a molecular weight of 186.13. The compound is soluble in water, but insoluble in alcohol or ether. EDDN has a heat of combustion of 374.7 kilocalories per mole at constant pressure, a heat of formation of 156.1 kilocalories per mole, and a heat of explosion of 127.9 to 159.3 kilocalories per mole. Eutectics are formed with ammonium nitrate, but EDDN is immiscible with molten TNT. An aqueous solution of EDDN is distinctly acidic. EDDN has been used to a limited extent as a bursting charge pressed in shells and as a cast charge in eutectic mixtures with ammonium nitrate. Mixtures with wax were used in boosters during World War II by the Germans.

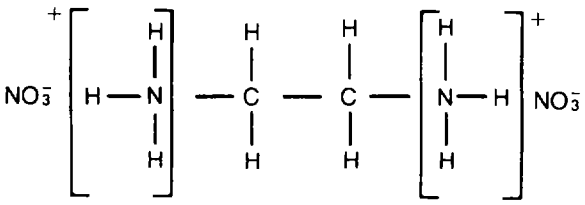


Figure 8-21. Structural formula for EDDN.

(2) EDDN is produced by neutralization of ethylenediamine dihydrate with concentrated nitric acid. This is followed by the concentration and crystallization of the salt formed.

(3) EDDN is more sensitive to shock than TNT, having impact test values of nine inches and 75 centimeters, respectively, with the Picatinny and Bureau of Mines apparatuses. In rifle bullet impact tests with a charge of specific gravity 1.0 no detonations occurred on the impact of bullets with velocities below 960 meters per second and incomplete detonations occurred with bullet velocities around 1,000 meters per second. EDDN is less sensitive to initiation than TNT, requiring a minimum detonating charge of 0.10 gram of tetryl according to the sand test. Two grams of mercury fulminate are required for the initiation of a 50 gram sample pressed to a specific gravity of 1.23 in a paper cylinder 30 millimeters in diameter. In a gap test a minimum separation of 3.75 centimeters was found with paper cartridges each containing a 50 gram sample pressed to a density of 0.75. The explosion temperature test value of EDD is 445°C, as compared with 475°C for TNT. A small sample placed in a test tube ignites in six seconds when plunged into a bath preheated to 370°C, and in one second when the temperature of the bath is increased to 430°C. EDDN is ignited by open flame after one minute and continues to burn at the rate of 1.5 centimeters per minute.

(4) The sand test indicates EDDN is 96 percent as brisant as TNT, and plate dent test values are practically the same for the two explosives. The detonation velocity for a sample of EDDN with a specific gravity of 1.00 is 4,650 meters per second, 6,270 meters per second at a specific gravity of 1.33, and 6,915 meters per second at a specific gravity of 1.50. EDDN is indicated to be 114 percent and between 120 and 125 percent as powerful as TNT by the ballistic pendulum and Trauzl lead block tests, respectively.

(5) When heated in vacuum EDDN vaporizes and condenses without noticeable decomposition. When heated at 10 millimeters of pressure in an atmosphere of nitrogen or air, autocatalytic decomposition occurs between 230°C and 360°C. EDDN is hygroscopic to the extent of 1.24 percent at 90 percent relative humidity and 25°C. In the 120°C vacuum stability test, five milliliters of gas are evolved. Because of poor solubility, hygroscopicity, and acidity characteristics, EDDN is not very satisfactory for use as a military explosive and is an inferior substitute for TNT.

d. Ethylenedinitramine (Haleite).

(1) This compound is also known as N' N'-dinitroethylene diamine; ethylene dinitramine; or 1,2-dinitrodiaminoethane, and is sometimes designated EDNA. The name Haleite is in recognition of the development of this compound as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal. The compound (figure 8-22) is white with an orthorhombic crystal structure, a nitrogen content of 37.33 percent, an oxygen balance to CO_2 of-32 percent, an oxygen balance to CO of-10.5 percent, and a molecular weight of 150.10. The density of the crystals vary from 1.66 to 1.77 depending on the solvent from which the crystallization took place. Packing density as a function of pressure is shown in table 8-22.

Table 8-22. Haleite Packing Density

Pressure grams per cubic kilopascals	Pressure pounds square inch	Density grams per cubic centimeter
34,475	5,000	1.28
68,950	10,000	1.38
82,740	12,000	1.41
103,425	15,000	1.44
137,900	20,000	1.49

Haleite melts with decomposition at 177.30C, but does not extrude. The solubility of Haleite in water at 10°, 20°, 50°, 75°, and 95°C is 0.10, 0.25, 1.25, 5.0, and 16.4 grams, respectively, per 100 grams of solvent. In 95 percent ethanol at 10°, 20°, 50°, 75°, and 78.5°C, Haleite is soluble to the extent of 0.55, 1.00, 3.50, 10.07, and 11.5 grams, respectively, per 100 grams of solvent and is soluble in methanol. Haleite is insoluble in ether, but in actetone at 200C, Haleite is soluble to the extent of 8.2 grams per 100 grams. Haleite is soluble in nitromethane, nitrobenzene, and dioxane, which can be used to recrystallize the explosive. The heat of combustion of Haleite at constant pressure is 2,477 calories per gram, from which a heat of formation value of 20.11 kilogram-calories per mole is derived. The heat of explosion is 1,276 calories per gram.

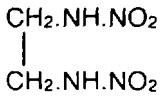


Figure 8-22. Structural formula for Haleite.

(2) Haleite is an explosive that combines the properties of a high explosive like TNT and an initiating agent like mercury fulminate or lead azide, possessing a high brisance and comparatively low sensitivity. No other high explosive is known which has such a low sensitivity to impact and at the same time so readily explodes by heat. Another important characteristic of Haleite is a relatively low explosion temperature, approaching that of mercury fulminate or nitroglycerin. Haleite lacks oxygen for complete combustion to CO_2. Mixtures with oxidizing agents such as ammonium nitrate, potassium chlorate, and ammonium perchlorate yield a series of explosive mixtures more powerful than Haleite.

(3) The first step in the manufacture of Haleite is the production of ethylene diamine. One reaction employed is:

$$CH_20+HCN \rightarrow HOCH_2CN$$

$$HOCH_2CN + NH_3 \rightarrow H_2NCH_2CN+H_20$$

$$H_2NCH_2CN+NH_3 \rightarrow \begin{matrix} CH_2.NH_2 \\ | \\ CH_2.NH_2 \end{matrix}$$

The yield of the second reaction is 82 percent. The third reaction is carried out under high pressure. The ethylene diamine is converted to ethyleneurea, 2-imidazolidinone, by either reacting with diethylcarbonate or carbon dioxide. The reaction with diethylenecarbonate is not generally used because the yield is only 42 percent of theoretical and the reaction requires the use of high pressure and high temperature for an extended period of time. The reaction with carbon dioxide is carried out under 820 atmospheres of pressure at 220°C. The reactions are shown in figure 8-23. The ethyleneurea can be nitrated with either concentrated nitric acid or a mixture of nitric and sulfuric acids. In the latter case, 10 parts of mixed acid containing 74.0 percent sulfuric acid, 15.4 percent nitric acid, and 10.6 percent water are cooled to 10°C or less and agitated. One part of ethyleneurea is added at such a rate that the temperature does not rise above 10°C. After the last portion of the ethyleneurea has been added, stirring is continued for five minutes. A variation of this process is to dissolve 1 part of ethyleneurea in 7.5 parts of 95 percent sulfuric acid, while maintaining the temperature at 20°C. This solution then is added slowly, while maintaining the temperature of the mixture at 0°C or less, to 3.33 parts of a mixed acid containing 15.8 percent sulfuric acid, 66.7 percent nitric acid, and 17.5 percent water. When addition is complete, the temperature is increased to 10°C and maintained at that value for two hours. The dinitroethyleneurea is caught on a filter and

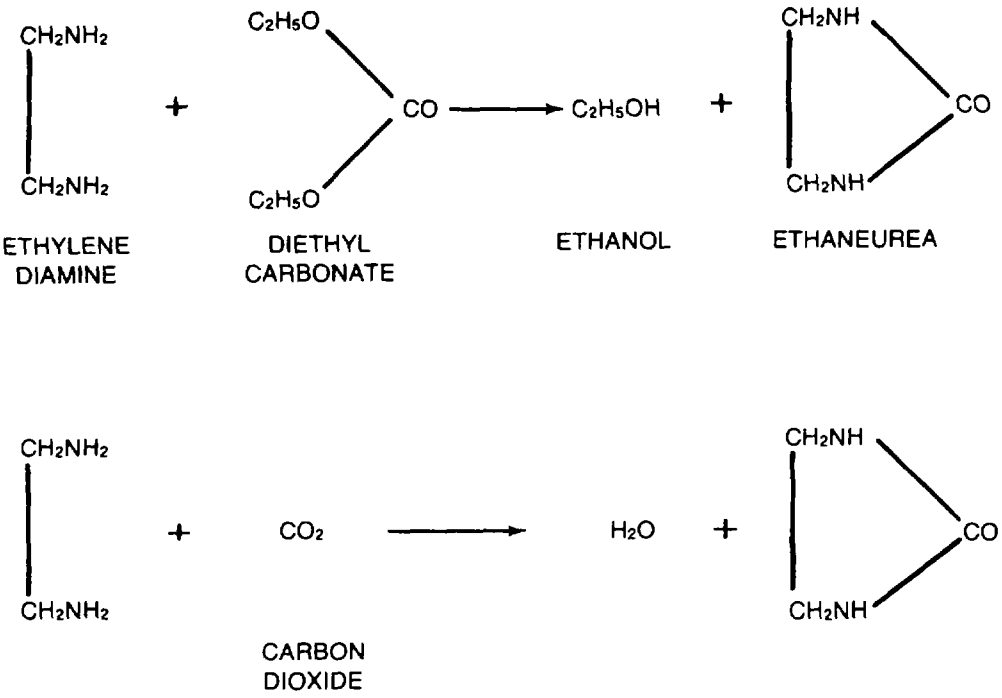


Figure 8-23. Production of ethyleneneurea.

washed with ice water until the washings are almost neutral. Additional dinitroethyleneurea is recovered by drowning the spent acid in ice water. A total yield of 97 percent of the theoretical is obtainable. One part dinitroethyleneurea, by weight, is suspended in seven parts water and boiled until the evolution of carbon dioxide ceases. The reaction is shown in figure 8-24. Haleite separates as shining crystals when the solution is cooled to room temperature. This is caught on a filter, washed with cold water, and dried. The total yield of Haleite from ethyleneurea is approximately 92 percent of the theoretical. Another method of producing Haleite is by treating dinitroethylenediurethane with an alcoholic solution of ammonia followed by acidifying with hydrochloric acid. This reaction is shown in figure 8-25.

(4) One grade of Haleite is specified for military purposes. This complies with the following requirements:

Color: White to buff.
Moisture: Maximum, 0.10 percent.
Melting point: Minimum, 174.0°C.
Purity: Minimum, 99.0 percent.
Water insoluble matter: Maximum, 0.10 percent.
Grit: None.
120°C vacuum stability test: Maximum, 5.0 milliters of gas in 40 hours.
Granulation:

	Percent
Through US No. 10 sieve, minimum	100
Through US No. 100 sieve, maximum	20

(5) Impact tests show Haleite to be slightly more than twice as sensitive as TNT, with a 48 centimeter drop height versus 100 centimeters for TNT. In the rifle bullet impact test for 100 trials, there were 60 partial detonations, 20 burnings, and 20 unaffected. Haleite is unaffected by either the fiber or steel shoe in the pendulum friction test. A minimum initiating charge of 0.21 grams of mercury fulminate or 0.13 grams of lead azide are required for initiation. In the gap test, a minimum separation of 14 centimeters was found for two paper cartridges, each containing 50 grams of Haleite at a density of 0.80. This value is 64 percent of that for tetryl at a density of 0.94. The explosion temperature test value is 190°C. The 0.1 second explosion temperature test value is 265°C. Haleite flammability index is 138 seconds.

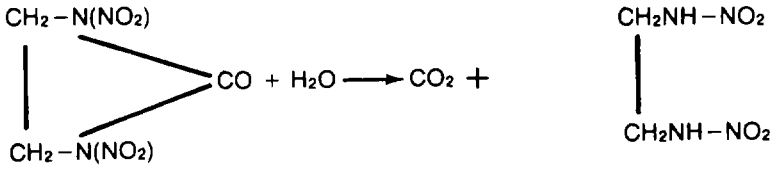


Figure 8-24. Boiling of dinitroethyleneurea.

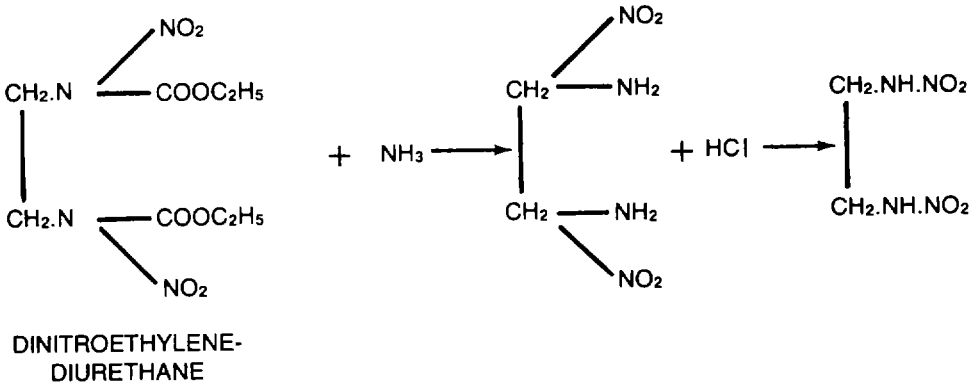


Figure 8-25. Production of Haleite.

(6) As measured by the sand test, Haleite has a brisance of 109 to 1 19 percent of that for TNT. The plate dent test indicates a brisance value of 113 to 122 percent of TNT. The plate cutting test indicates a brisance equal to that of PETN. A fragmentation test using a three inch, high explosive, M42A shell with a charge of 95 percent Haleite and 5 percent wax at a density of 1.56 was found to produce 117 percent as many fragments as TNT. Other fragmentation test values varied from 136 to 147 percent of TNT. The detonation velocity for a sample at a density of 1.55 grams per cubic centimeter is reported as 7,883 meters per second. For a sample of density 1.50, a detonation velocity of 7,580 meters per second was reported and a velocity of 5,650 meters per second for a sample of density 1.0. The ballistic mortar tests indicate Haleite is 136 to 140 percent as powerful as TNT. The Trauzl test indicates a power of 122 to 143 percent of TNT.

(7) In the 100°C heat test, a 0.2 percent weight loss was reported in the first 48 hours, and 0.3 percent was lost in the second 48 hours. No explosions occurred. The 135°C heat test results are satisfactory. The 75°C international heat test result is that a 0.01 percent loss occurs in 48 hours. Decomposition temperatures are 170°C in 20 seconds, 1730C in 15 seconds, 178°C in 10 seconds, 1890C in 5 seconds. At higher temperatures, Haleite darkens to a red brown with the evolution of NO_2. Haleite is hygroscopic to the extent of 0.01 percent at 90 percent relative humidity. In the vacuum stability test at 1 00°C with a five gram sample, 0.5 cubic centimeters of gas are evolved in 48 hours. At 120°C, 1.5 to 2.4 cubic centimeters of gas are evolved, and at 135°C more than 11 cubic centimeters are evolved. Tests have shown Haleite to be volatilized at the rate of 0.05 percent per hour when heated at 100°C in an open dish. Storage tests have shown dry Haleite to be of unimpaired stability after storage at 65°C for five months or 50°C for 30 months. Therefore, Haleite is considered to be of satisfactory stability at the normal exposure temperatures for storage and handling. Dry Haleite does not cause corrosion of aluminum, brass, copper, mild steel, stainless steel, cadmium, nickel, or zinc. Magnesium and magnesium alloys are slightly affected by dry Haleite. Stainless steel is not corroded by wet Haleite, but copper, brass, mild steel, cadmium, nickel, and zinc are heavily corroded in the presence of as little as 0.5 percent moisture.

e. Nitroguanidine (NQ).

(1) This explosive is also known as picrite or guanylnitramine. The compound (figure 8-26) has a nitrogen content of 53.84 percent, an oxygen balance to CO_2 of -30.8 percent, a theoretical maximum density of 1.81 grams per cubic centimeter, a nominal density of 1.55 to 1.75 grams per cubic centimeter, and a molecular weight of 104.1. The melting point of nitroguanidine varies somewhat with the rate of heating. The pure material melts with decomposition at 232°C, but values from 220°C to 250°C are obtainable with various heating rates. At least two crystalline forms exist for nitroguanidine; alpha and beta. The alpha form is obtained when nitroguanidine is dissolved in concentrated sulfuric acid and then drowned with water. The crystals formed are long, thin, lustrous, flat needles that are tough and very difficult to pulverize. The needles have a double refraction value of 0.250. This is the form most commonly used in the explosive industry. The beta form crystallizes from hot water in fern-like clusters of small, thin, elongated plates. The plates have a double refraction value of 0.185. The beta form may be converted into the alpha by dissolving in concentrated sulfuric acid and drowning in water. Neither form, however, is converted into the other by recrystallization from water, and the two forms can be separated by fractional crystallization from water. The beta form may also be converted to the alpha form by decomposition of the nitrate or hydrochloride formed by beta nitroguanidine. When alpha nitroguanidine is decomposed by heat, some beta nitroguanidine is formed; but the beta compound generally is obtained by the nitration of the mixture of guanidine sulfate and ammonium sulfate, resulting from the hydrolysis of dicyandiamide, $H_2N.C(:NH).NH.CN$, by sulfuric acid. The alpha form is obtained by the reaction of guanidine and nitric acid to form the nitrate. The nitrate is dehydrated to form the nitrocompound. Both forms of nitroguanidine have the same melting point and are alike in most chemical and physical properties. The unit cell dimensions are 17.58 Angstroms, 24.84 Angstroms, and 3.58 Angstroms. There are 16 molecules per cell. The refractive index is; alpha equals 1.526, beta equals 1.694, and gamma equals 1.81. However, they differ slightly in solubility in water except at 25°C and 100°C, where their solubility curves cross, having values of 0.42 to 0.44 grams per 100 milliliters at 25°C and 8.25 grams per 100 milliliters at 100°C. Solubility between 25°C and 100°C is slightly lower for the alpha than for the beta form. At 0°C the solubility for both forms is about 0.12. Both forms are slightly soluble in alcohol and nearly insoluble in ether. In a solution of one normal potassium hydroxide at 250°C the solubility is 1.2. Table 8-23 lists the solubility for nitroguanidine in sulfuric acid at various concentrations and temperatures.

Table 8-23. Solubility of Nitroguanidine in Sulfuric Acid

Sulfuric acid percentage in water	Temperature °C	Grams dissolved per 100 cubic centimeters
0	0	0.12
	25	0.42
15	0	0.3
	25	0.55
20	0	0.45
	25	1.05
25	0	0.75
	25	1.8
30	0	1.3
	25	2.9
35	0	2.0
	25	5.2
40	0	3.4
	25	8.0
45	0	5.8
	25	10.9

Nitroguanidine has a crystal density of 1.715, but because of the toughness and flexibility of the crystals, a density of only 0.95 is obtained when subjected to a pressure of 3,000 psi. The heat of combustion of nitroguanidine at constant pressure is 210.4 kilocalories per mole, and from this is derived a heat of formation value of 20.29 kilogram-calories per mole. The heat of detonation is 1.06 kilocalories per gram with liquid water and 880 calories per gram with gaseous water. The volume of gas produced is 1077 cubic centimeters per gram.

Nitroguanidine is essentially nonvolatile. The vapor pressure is given by the equation:

$\log pa = 13.01 - 7014/T(°C)$

for 70.70C < T <174.20°C

One torr equals 133 pa. The specific heat, in calories per gram per degree centigrade, for high bulk density nitroguanidine is:

$$0.269+(7.0\times10^{-4})T \text{ for } 37°C < T < 167°C$$

The specific heat for low bulk density nitroguanidine is:

$$0.242+(11.1\times10^{-4})T \text{ for } 370°C < T < 167°C$$

Because of the low temperature of explosion, about 2,098°C, nitroguanidine is used in triple-base propellants that are practically flashless and less erosive than nitrocellulose-nitroglycerin propellant of comparable force. When used by the Germans in World War II in antiaircraft guns, a nitroguanidine propellant increased the barrel life from 1,700 firings to about 15,000 firings.

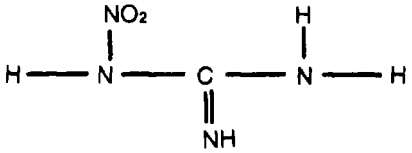


Figure 8-26. Structural formula for nitroguanidine.

(2) Nitroguanidine is chemically reactive because of a free amino group as well as a nitro group and a tendency toward dearrangement. With hot concentrated nitric acid, nitroguanidine forms a nitrate that melts at 147°C and, with strong hydrochloric acid, yields a crystalline hydrochloride. On reduction, nitroguanidine yields nitrosoguanidine, $H_2N.C(NH).NH.NO$, and then aminoguanidine, $H_2N.C(:HN).NH.NH_2$. With a solution of diphenylamine in sulfuric acid, nitroguanidine gives a blue color. When tested with ferrous ammonium sulfate and sodium hydroxide, a fuchsine color is developed. When warmed with water and a large excess of ammonium carbonate, nitroguanidine forms guanidine carbonate. With an aqueous solution of hydrazine, nitroguanidine reacts to form N-amino, N'-nitroguanidine, $N_2N.HN.C(:NH).NH.NO_2$, which melts at 182°C. On being heated or undergoing reaction in sulfuric acid solution, nitroguanidine appears to undergo dearrangement according to two modes:

$$H_2N.C.(:NH).NH.NO_2 \rightarrow NC.NH_2 + H_2N.NO_2$$

Cyanamide
Nitramide

$$H_2N.C(:NH).NH.NO_2 \rightarrow NH_3 + NC.NH.NO_2$$

Ammonia
Nitrocyanamide

When decomposed by heating above the melting point, the products obtained from nitroguanidine are water, nitrous oxide, cyanamide, melamine, ammonia, cyanic acid, cyanuric acid, ammeline, and ammelide. These are the products to be anticipated from the dearranged compound. The reaction and decomposition of the primary products of decomposition form carbon dioxide, urea, melam, melem, mellon, nitrogen, hydrocyanic acid, cyanogen, and paracyanogen. In aqueous solution, nitroguanidine dearranges in both of the above modes, but this is only to a small degree, unless another compound is present to react with one of the products of dearrangement. As a result of this, nitroguanidine is relatively stable in aqueous solution. A saturated aqueous solution at 25°C has a pH value of 5.5. After being heated at 60°C for two days, such a solution has a pH value of 8.5. In the absence of ammonia and in the presence of a primary aliphatic amine, nitroguanidine reacts to form an alkylnitroguanidine as if the amine reacted with nitrocyanamide present by dearrangement. A solution of either form of nitroguanidine in concentrated sulfuric acid acts chemically as if the nitroguanidine had dearranged into nitramide and cyanamide, although alpha nitroguanidine is precipitated if the solution is poured into water. When such a solution is warmed, nitrous oxide and a little nitrogen are evolved at first from the dehydration of nitramide. Later and more slowly, carbon dioxide is liberated resulting from the hydrolysis of cyanamide. After standing for some time, a sulfuric acid solution of nitroguanidine no longer gives a precipitate of nitroguanidine when diluted with water. Although a freshly prepared solution contains no nitric acid, this is formed by the hydration of nitramide, if a material that can react with nitric acid is present. Consequently, nitroguanidine splits off the nitro group quantitatively and the purity of the material can be determined by the nitrometer method.

(3) The specification for military nitroguanidine covers two types of material and two classes with respect to granulation. The requirements with which the explosive must comply are as follows:

	Type I, %		**Type II, %**	
Properties	**Min**	**Max**	**Min**	**Max**
Purity (assay)	98.0	-	99.0	-
Ash content	-	0.30	-	0.30
pH value	4.5	7.0	4.5	7.0
Acidity (as sulfuric acid)	-	0.60	-	0.06
Total volatiles	-	0.25	-	0.25
Sulfates (as sodium sulfate)	-	0.20	-	0.20
Water insoluble impurities	-	0.20	-	0.20

Granulation requirements are as follows:

Type	Class	Minimum in microns	Maximum in microns
I	1	4.3	6.0
	2	-	3.3
II	1	3.4	6.0
	2	-	3.3

(4) Several methods for the preparation of nitroguanidine are known. The earliest method was by the direct nitration of guanidine thiocyanate with mixed acids. Guanidine thiocyanate is one of the cheapest and easiest to prepare of the guanidine salts. However, this method of production also produced sulfur compound impurities which attacked nitrocellulose. This lowered the stability of propellant compositions to an unacceptable degree, thus precluding early use of the compound as an ingredient in nitrocellulose based propellants. A more pure form of nitroguanidine that does not contain the sulfur compound impurities can be prepared in one of several known ways. In one method equimolecular quantities of urea and ammonium nitrate are fused according to the equation:

$$H_2N.CO.NH_2+NH_4NO_3 \rightarrow H_2N.C(:NH).NH.NO_2 + 2H_20$$

The product is then recrystallized from boiling water. The yield of this method is approximately 92 percent of the theoretical. Another method of preparation involves heating a solution of equimolecular quantities of cyanamide and ammonium nitrate to 160°C at a pressure of 200 pounds. The reaction proceeds according to the equation:

$$H_2N.CN + NH_4NO_3 \rightarrow H_2N.C(:NH).NH.NO_2 + H_2O$$

The product is then recrystallized from boiling water. The yield of this method is approximately 88 percent. A third method involves the production of guanidine nitrate as a precursor to the nitroguanidine. Two reactions can be employed to produce guanidine nitrate. The first reaction:

$$H_2N.C(:NH).NH_2 + HNO_3 \rightarrow H_2N.C(:NH).NH_2.HNO_3$$

is simply the reaction between guanidine and nitric acid. The second reaction:

$$H_2NC(:NH).NH.CN + NH_4NO_3 \rightarrow H_2N.C(:NH).NH_2HNO_3 + NC.NH_2$$

is the reaction between dicyandiamide and ammonium nitrate. As the guanidine or dicyandiamide can be produced from the raw materials coke, limestone, atmospheric nitrogen, and water, the production of nitroguanidine does not involve the use of special natural resources. However, a very large amount of electrical energy is required for the production of dicyandiamide or guanidine. Dehydration of guanidine nitrate to nitroguanidine is affected by adding 1 part of the nitrate to 2.3 parts by weight of sulfuric acid (95 percent), so that the temperature does not rise above 10°C. The reaction proceeds according to the equation:

$$H_2N.C(:NH).NH_2.HNO_3 \rightarrow H_20 + H_2N.C(:NH).NH.NO_2$$

As soon as all the nitrate has been dissolved, the milky solution is poured into seven and one-half parts of ice and water. The mixture is kept ice-cold until precipitation is complete, when the nitroguanidine is caught on a filter, washed with cold water, and redissolved in 10 parts of boiling water. The nitroguanidine recrystallizes when the solution cools. The yield is approximately 90 percent of the theoretical.

(5) Impact sensitivity test results are 47 centimeters using the standard two kilogram weight in the Bureau of Mines apparatus and 26 inches using a nonstandard weight of one pound in the Picatinny Arsenal apparatus. Even when a factor is applied to correct for the nonstandard weight, the values obtained are inconsistent. The preponderance of evidence, however, is that this explosive is considerably less sensitive than TNT to impact as well as friction and initiation. Gap test results for nitroguanidine are shown in table 8-24. Nitroguanidine is unaffected by the rifle bullet impact test and both the fiber and steel shoes in the pendulum friction test. The result of the five second explosion temperature test is 275°C. A minimum charge of 0.20 grams of lead azide or 0.10 grams of tetryl are required for initiation. Sensitivity to initiation varies somewhat with crystal size. Larger quantities can be detonated by a blasting cap containing 1.5 grams of mercury fulminate. Nitroguanidine, therefore, may be classified as one of the least sensitive of military explosives.

Table 8-24. Gap Test Results for Nitroguanidine

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
LANL small scale gap test	1.575 (pressed)	11.8	no explosions
LANL large scale gap test	1.715 (pressed)	3.5	no explosions
	1.609 (pressed)	9.6	5.00

(6) The sand test indicates nitroguanidine to be between 73.5 and 84 percent of TNT. At a density of 1.5 grams per cubic centimeter, the plate dent test indicates a brisance of 95 percent of TNT, and the lead block compression test indicates 73 percent of TNT. The critical diameter at a density of 1.52 grams per cubic centimeter is between 1.27 millimeters and 1.43 millimeters. At a density of 1.70 grams per cubic centimeter the detonation velocity is 8.100 meters per second. At a specific gravity of 1.5 the velocity is 7,650 and at a specific gravity of 1.0 the velocity is 5,360. At a density of 1.55 grams per cubic centimeter, nitroguanidine has a higher velocity of detonation than TNT at the same density; 7,650 compared to 6,900 for TNT. The detonation velocity as a function of density is given by the equation:

$$d = 1.44 + 4.015p$$

where d is in kilometers per second and p, the density, is in grams per cubic centimeter. By the Trauzl test, nitroguanidine is 78 to 101 percent as powerful as TNT, and by the ballistic mortar test, 104 percent as powerful. The temperature of explosion is about 2098°C as compared to 2820°C for TNT. The relatively small heat of explosion explains nitroguanidine's cooling effect when present in propellent compositions.

(7) Nitroguanidine begins to undergo decomposition at a higher temperature, 232°C, than does TNT, 80°C to 200°C. The results of the 75°C international test is a 0.04 percent weight loss in 48 hours. The 100°C heat test results are 0.48 percent weight loss in the first 48 hours, 0.09 percent in the second 48 hours and no explosions in 100 hours. Vacuum stability tests at 120°C show nitroguanidine and TNT to be of the same order of 'stability. As both are essentially nonhygroscopic and very slightly soluble in water, the impairment of stability by moisture is not a practical problem. In the LLNL reactivity test, 0.02 to 0.05 cubic centimeters of gas are evolved per 0.25 grams of sample. Propellant compositions containing nitroguanidine have been found to be of a high order of stability; indications are that the nitroguanidine acts to some extent as a stabilizer, since such compositions generally do not liberate red fumes when subjected to the 65.5°C surveillance test. The DTA curve for nitroguanidine is shown in figure 8-27. The TGA curve is shown in figure 8-28.

f. 2, 4,6Trinitrophenylmethylnitramine (Tetryl).

(1) This explosive is also known as: 2,4,6tetranitro-N-methyl aniline; N-methyl-N,2,4,6tetranitro-benzenamine; 2,4,6-trinitrophenylmethylnitramine; tetranitromethylamulene; or picrylmethylnitramine and is sometimes referred to as pyronite, tetrylit, tetralite, tetralita, or CE. The compound (figure 8-29) is colorless when freshly prepared and highly purified, but rapidly acquires a yellow color when exposed to light. Tetryl has a nitrogen content of 24.4 percent, an oxygen balance to CO_2 of-47 percent, a nominal density of 1.71 grams per cubic centimeter with a theoretical maximum density of 1.73 grams per cubic centimeter, and a molecular weight of 287.15. The melting point of the pure substance is 129.45°C and of the technical grade, 129°C. Melting is accompanied by partial decomposition. Repeated solidification and melting rapidly increase the degree of decomposition. Tetryl has a scratch hardness of less than one on the Mohs' scale and therefore the crystals are slightly softer than talc. The crystals are monoclinic with unit cell dimensions of a =14.13 Angstroms, b =7.37 Angstroms, c =10.61 Angstroms. There are four molecules per unit cell. The refractive index is: alpha, 1.546; beta, 1.632; gamma, 1.74. Table 8-25 lists the density of tetryl as a function of loading pressure.

Table 8-25. Density as a Function of Loading Pressure for Tetryl

Loading pressure in kilopascals	Loading pressure in pounds per square inch	Density in grams per cubic centimeter
20,685	3,000	1.40
34,475	5,000	1.47
68,950	10,000	1.57
82,740	12,000	1.60
103,425	15,000	1.63
137,900	20,000	1.67
206,850	30,000	1.71
	cast	1.62

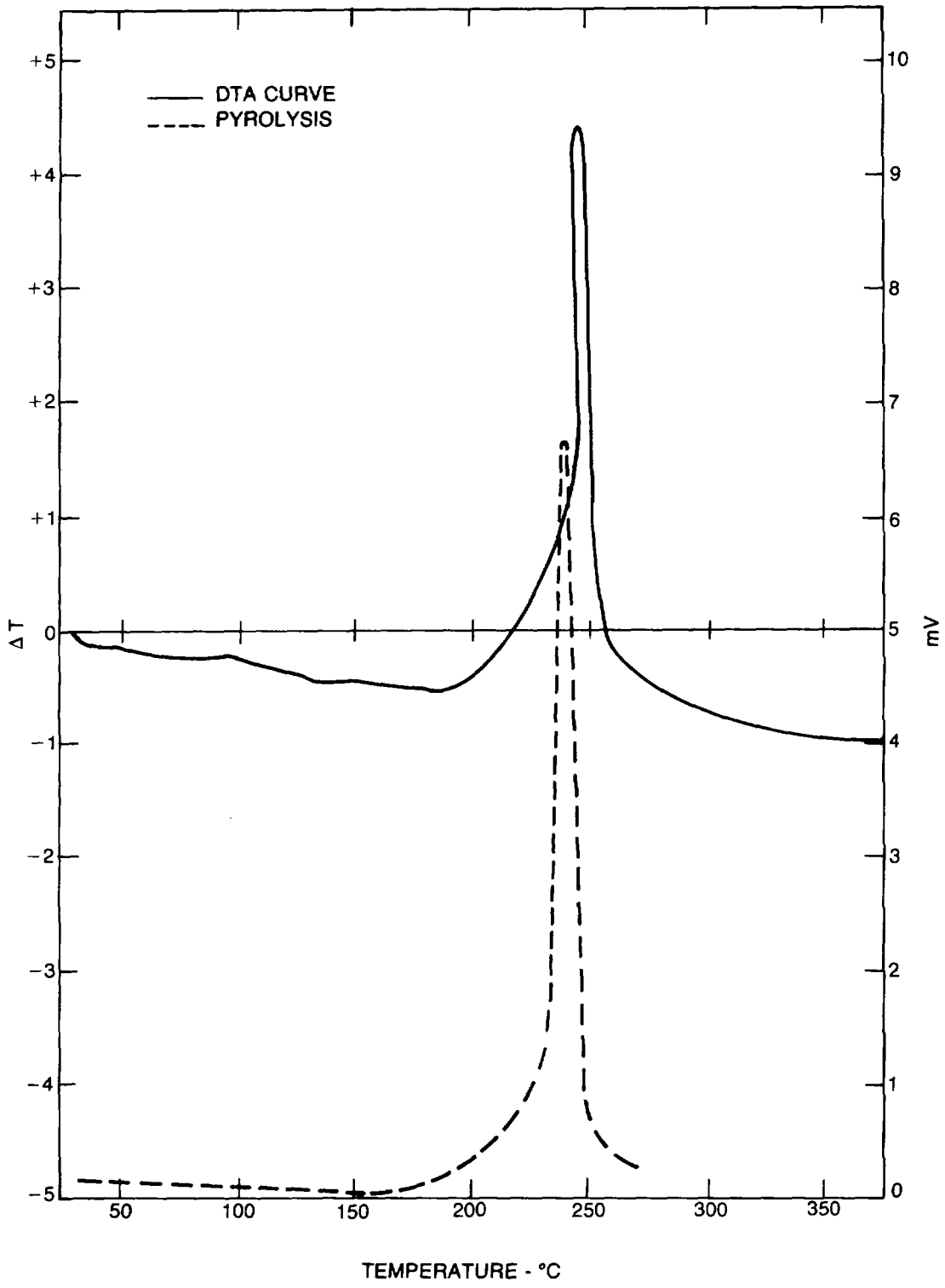


Figure 8-27. DTA curve for nitroguanidine.

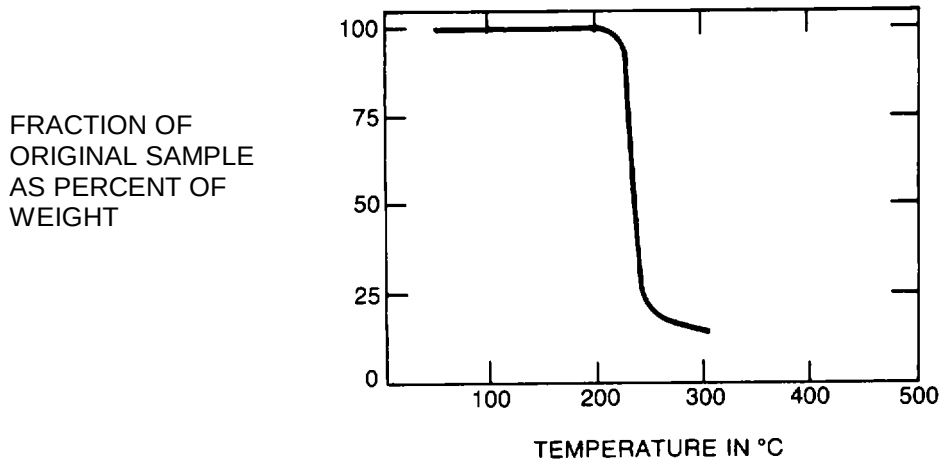


Figure 8-28. TGA curve for nitroguanidine.

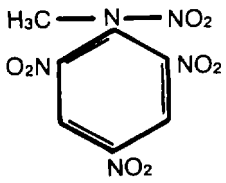


Figure 8-29. Structural formula for tetryl.

Over the temperature range of 200° to 403° Kelvin, the specific heat of tetryl as a function of temperature has been found to be

$$\text{Specific heat} = 0.213 + (2.18 \times 10^{-4})T - (3.73 \times 10^{-7})T^2$$

where T is in degrees Kelvin and the specific heat is in units of calories per gram per degree centigrade. Table 8-26 lists the dielectric constant for tetryl at various densities.

Table 8-26. Dielectric Constant of Tetryl

Density grams per cubic centimeter	Dielectric constant measured at 35 giga cycles
0.9	2.059
1.0	2.163
1.4	2.782
1.5	2.905
1.6	3.097
1.7	3.304

Tetryl has a heat of fusion of 5.9 kilocalories per mole and entropy of fusion of 13.7 eu. The heat of vaporization value is 26 kilocalories per mole, the coefficient of thermal expansion is 0.32x10-3 per degree, and the thermal conductivity in cgs units is 6.83 x10-4 at a density of 1.53 grams per cubic centimeter. Tetryl's heat of combustion at constant pressure is 2,914 calories per gram. The heat of formation value is 4.67 to 7.6 kilogram-calories per mole.The vapor pressure in torr of tetryl is given by the equation:

$$\log p = 13.71 - 6776/T(K)$$

for 85°C < T < 106°C

Tetryl dissolves readily in concentrated nitric acid and moderately well in other mineral acids but is soluble to the extent of only 0.3 percent in the spent acid after manufacture. Table 8-27 lists tetryl solubility in various solvents at the temperatures given. Benzene holds more tetryl in solution if a solution with solid tetryl present is cooled to a given temperature than if a mixture of benzene and an excess of tetryl is heated to and maintained at a given temperature. At 15°C, 25°C, 35°C, 45°C, and 55°C, tetryl has respective supersolubility values of 10.2, 12.2, 14.9, 18.25, and 22.5 and subsolubility values of only 3.9, 5.5, 7.4, 9.7, and 13.25 grams per 100 grams of benzene.

Table 8-27. Solubility of Tetryl in Various Solvents

Solvent	Grams per 100 grams of solvent											
	0°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C	120°C
Water	0.0050	-	0.0075	-	0.0110	-	-	-	0.810	-	0.184	-
Carbon tetrachloride	0.007	-	0.015	-	0.058	-	0.154	-	-	-	-	-
Ether	0.188	0.330	0.418	0.493	-	-	-	-	-	-	-	-
95% Ethanol	0.320	0.425	0.563	0.76	-	1.72	-	5.33 at 75°C	-	-	-	-
Chloroform	0.28	-	0.39	-	1.20	-	2.65	-	-	-	-	-
Carbon disulfide	0.009	0.015	0.021	0.030	-	-	-	-	-	-	-	-
Ethylene dichloride	-	4.5 at 25°C	-	-	-	-	-	45 at 75°C	-	-	-	-
Acetone	-	-	75	95	116	138	-	-	-	-	-	-
Trichloroethylene	0.007	-	0.12	-	0.26	-	-	-	1.50	1.76 at 86°C	-	-
Ethyl acetate	-	-	40 approx.	-	-	-	-	-	-	-	-	-
Toluene	-	-	8.5	-	-	-	-	-	-	-	-	-
Xylene	-	-	3.3	4.4	5.4	6.0	-	-	-	-	-	-
TNT	-	-	-	-	-	-	-	-	82	-	149	645

(2) Tetryl is highly resistant to attack by dilute mineral acids, but does react with concentrated acid or weak basic solutions. Trinitrophenyl methylamine (figure 8-30) is formed when tetryl reacts with concentrated sulfuric acid or with phenol. Prolonged boiling with dilute sulfuric acid has no effect. When tetryl is boiled with a solution of sodium carbonate, dilute aqueous sodium hydroxide, or dilute aqueous potassium hydroxide, the nitramino group is hydrolized as shown in figure 8-31. If this reaction is carried out in a nitrometer in the presence of mercury, the nitric acid is reduced to nitric oxide and can be measured. In benzene solution at ordinary temperatures, tetryl reacts with aniline to form 2,4,6trinitrodiphenylamine and methylnitramine as shown in figure 8-32. Aqueous sodium sulfide decomposes tetryl completely into nonexplosive, water soluble products. The reaction is relatively slow unless the solution is heated to 80° to 90°C. Prolonged heating of tetryl at 120°C yields picric acid. Tetryl is reduced and hydrolized to 2,4,6-triaminophenol by the action of tin and hydrochloric acid. Tetryl and TNT form an addition compound with a mole ratio of one to two, respectively. An addition compound is also formed with naphthalene with a mole ratio of one to one. Tetryl forms a eutectic mixture with 76.5 percent trinitro-m-xylene that has a melting point of 118.8°C, and with 29.5 percent trinitroanisole that has a melting point of 22.8°C.

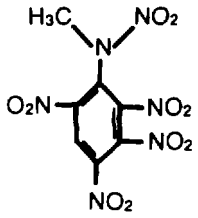


Figure 8-30. Trinitrophenyl methylamine.

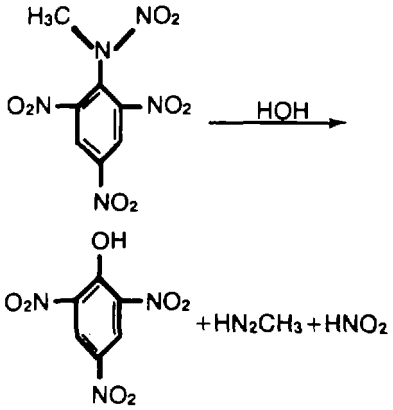


Figure 8-31. Hydrolysis of tetryl.

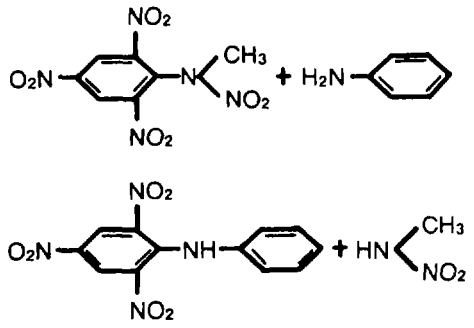


Figure 8-32. Reaction of tetryl with aniline.

(3) A number of homologs and analogs of tetryl are known. Figure 8-33 shows some examples.

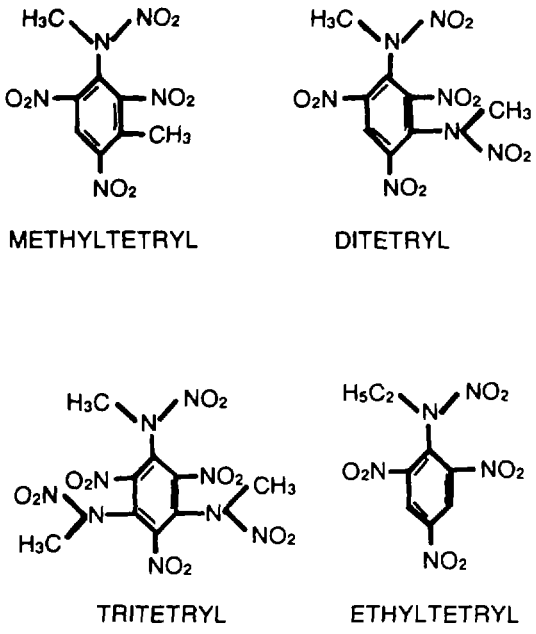


Figure 8-33. Homologs and analogs of tetryl.

(4) Tetryl is fairly resistant to degradation by gamma radiation. Exposure to a 10^4 Curie C_o^{60} source, which emits gamma rays at 1.173 and 1.332 million electron volts, produced some erratic results, but on the whole the changes induced by this exposure were not great. A sample exposed to 1.4x107 R passed the 120°C vacuum stability test, but a sample exposed to 1.2x 108 R could only pass the 100°C test and failed in the 1200C test. Weight loss increased dramatically when exposure levels were increased from 1.3 x 108 R to 109 R. Irradiated samples did not show much change over control samples in the DTA test until exposure levels reached 1.2 x 108 R, and even at 109 R changes were moderate. The impact sensitivity, detonation velocity, and explosion temperature are only slightly affected by exposure to gamma radiation.

(5) Tetrylshows negligible reaction with: Adhesive EC 1099, Dapon resin, Delrin, Epoxy 907 adhesive, Galvanoplast, conductive paint, Glastimat No. 1, Lexan, Loctite 404, Molylube No. 18, Permacel PN 112 tape, Polyesters, polysulfide rubber sealant, polyurethane EP 626/628, RTV 102 and 732 vulcanizing rubbers, Silastic RTV 731 or 732 (uncured), Silicone No SE 1201 and No Q 95-011, urea-formaldehyde. Tetryl is also compatible with the following adhesives: Adiprene L-10Q, L-167 and LD-213, and Eastman 910.

(6) As of 1979 the United States has discontinued the use of tetryl. No new components are being designed with tetryl, and all components that contained tetryl are being redesigned to eliminate the tetryl. The reason for this action is the relative instability of tetryl after storage at elevated temperatures. Various NATO nations have not discontinued tetryl's use in boosters and lead charges.

(7) Two methods have been used extensively for the manufacture of tetryl. The first method uses methylamine (CH3NH2), a cheap commercial bulk chemical, in the production of dinitrophenylmethylamine from 2,4or 2,6-dinitrochlorobenzene by the reaction:

$C_6H_3(NO_2)_2Cl+CH_3NH_2 \rightarrow$

$HCl+C_6H_3(NO_2)2NH.CH_3$

This can be nitrated to tetryl with relative ease. A considerable amount of tetryl was prepared by this method in the United States during World War II. A variation on this method is used at the present time in Germany. The reaction between the 2,4or 2,6-dinitrochlorobenzene and methylamine is carried out in the presence of sodium hydroxide. The dinitrophenylmethylamine is then dissolved in sulfuric acid, which is made up from spent acid and contains some nitric acid, oxides of nitrogen and 16 percent water. This solution is then added to mixed acid containing 78 percent nitric acid, 6 percent sulfuric acid, and 16 percent water. The second method uses dimethylaniline as the starting material. The use of dimethylaniline has the disadvantage of requiring nitric acid for the removal of one methyl group by oxidation according to the equation:

$$C_6HN(CH_3)_2+10HNO_3 \rightarrow (NO_2)_3C_6H_2N\ (NO_2)CH_3+6NO_2+CO_2+8H_2O$$

This disadvantage is not shared by the first process described above. Direct nitration of dimethylaniline proceeds so violently that the reaction can be carried out only under specialized conditions. The dimethylaniline is converted to dimethylaniline sulfate by dissolving one part of the chemical in 14.4 parts of 96 to 99 percent sulfuric acid at 20°C to 30°C. Many years experience in tetryl manufacture has shown that the ratio of sulfuric acid to dimethylaniline should not be lower than 3: 1, since a smaller amount of sulfuric acid may be detrimental to the nitration process. However, the ratio of sulfuric acid to dimethylaniline must not be too high, otherwise tetryl yield is decreased. Sulfonation of the benzene ring will occur if the temperature is not maintained between 20°C and 40°C. A quantity of 15.4 parts of the solution of dimethylaniline sulfate is added in a nitrator to 9.2 parts of mixed acid which contains 66.7 percent nitric acid. 15.8 percent sulfuric acid, and 17.5 percent water. The contents of the nitrator are heated to 68°C then heating is discontinued. This step involves a reaction that oxidizes a methyl group and is highly exothermic. The temperature of the reaction must be maintained at 60°C to 72°C by external means, if necessary. For safe and efficient nitration, very vigorous stirring is essential to ensure that the reacting liquids are mixed almost instantaneously. The mixture is kept in this nitrator for a very short period, so the reaction may be incomplete. The contents of the nitrator are discharged via an overfall to a larger reactor that is also equipped with a stirrer. In this reactor, which is maintained at 70°C, the reaction is completed. Commercial dimethylaniline contains some methylaniline which is nitrated to 2,3,4,6-tetranitrophenylnitramine (also called m-nitroethyl) which in turn is readily hydrolyzed to 2,4,6-trinitro-3-hydroxyphenylmethylnitramine. The nitration and hydrolysis are shown in figure 8-34. The compound formed is readily soluble in water and easily removed. If the water content of the mixed acid is too high, benzene insoluble impurities are formed which are benzidine derivatives. The derivatives are shown in figure 8-35. After the reaction is completed in the reactor, the liquid which contains partially crystallized tetryl is allowed to run into a crystallizer which is maintained at 20°C. The crystallized product is discharged to a vacuum filter where the tetryl is collected and the spent acid is passed on to be renitrated. Tetryl must then be purified carefully to remove any tetranitrocompound and occluded acidity, which have adverse effects on the stability of tetryl. Most of the acidity is removed by washing with cold water. Treatment with boiling water decomposes any tetranitrocompound present and removes any products. If benzene is used as a solvent, the crude tetryl is dissolved, the solution is washed with water to remove residual acidity, and filtered to remove insoluble matter. Upon cooling the solution, the tetryl is precipitated, separated, and dried. If acetone is used as the solvent, the solution is neutralized and filtered and the tetryl is precipitated by mixing the solution with water. The acetone purification process is carried out on a continuous basis, while that with benzene is operated as a batch process. In the lab, high purity tetryl can be obtained by nitrating dimethylaniline with nitric acid, not mixed acid, in the presence of inert solvents such as dichloromethane, chloroform, or carbon tetrachloride.

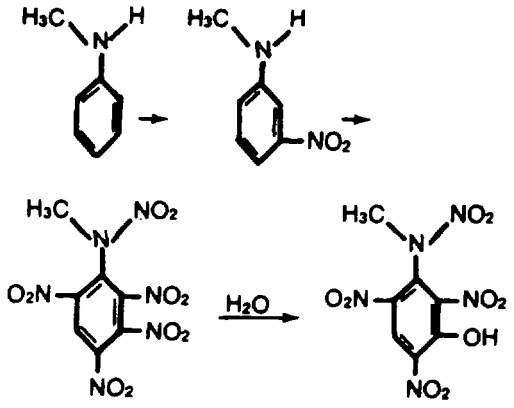


Figure 8-34. Nitration and hydroylsis of methylaniline.

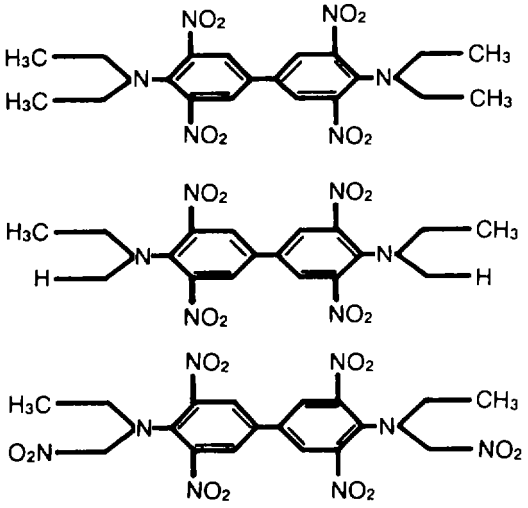


Figure 8-35. Benzidine derivatives during tetryl manufacture.

(8) One grade of tetryl is specified for military purposes. This complies with the following requirements:

Color:	Light yellow
Moisture and volatiles:	Maximum, 0.10 percent
Toluene insoluble matter:	Maximum, 0.10 percent
Grit:	3 particles
Acidity:	Maximum, 0.02 percent
Melting point:	Minimum, 128.8°C; maximum, 129.5°C

Granulation: Percent through US standard sieve:

No. 12, minimum	100
No. 16, minimum	95
No. 30, minimum	-
No. 40, maximum	-
No. 60, maximum	30
No. 100, maximum	5

A requirement also exists for an infrared spectrum with only certain specified peaks and no extraneous peaks. The requirement with respect to insoluble matter is included because of the marked desensitizing effect of such impurities. Freedom from grit is required because of the affect of grit on sensitivity to impact and friction.

(9) Impact and rifle bullet tests indicate tetryl is more sensitive than TNT. The pendulum friction test, however, produces no detonations with the steel shoe. The explosion temperature test value of tetryl is much lower than that of TNT. For tetryl dropped on a heated copper surface the results in table 8-28 were reported.

Table 8-28. Heat Initiation of Tetryl

Temperature in °C	Time to explosion in seconds
302	0.4
280	1.1
260	2.0
236	6.2

Slightly different results were obtained with confined samples of tetryl. The explosion times for 25 milligrams of tetryl in copper shells of 0.635 millimeter diameter submerged in a hot woods metal bath are shown in table 8-29.

Table 8-29. Heat Initiation of Confined Tetryl

Temperature in °C	Time to explosion in seconds
360	0.325
346	0.425
329	0.582
285	1.45
269	2.22
264	Does not detonate

When a 0.5 gram sample of tetryl is heated at a rate of 20°C per minute, ignition occurs between 190°C and 194°C. If the temperature of a sample is held at 180°C ignition occurs in 40 seconds. The minimum primary charges necessary for reliable detonation of tetryl with mercury fulminate is 0.20 to 0.29 grams and with lead azide is 0.025 to 0.10 grams. Tetryl containing 60 percent water cannot be detonated by a commercial detonator. Shock sensitivity as measured by the gap tests are summarized in table 8-30.

Table 8-30. Gap Test Results for Tetryl

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.687	2.5	7.80
	1.434	17.1	11.96
LANL small scale gap test	1.684 (pressed)	2.7	3.84
	1.676 (pressed)	3.1	4.04
	0.93 (bulk)	46.2	7.44
LANL large scale gap test	1.690 (not pressed)	2.3	59.82
	1.666 (pressed)	3.7	60.60
	0.85 (bulk)	50.9	69.2

The shock sensitivity of a lightly confined sample decreases as temperature decreases, but confined samples show only a slight tendency toward reduced shock sensitivity. Particle size has an effect on shock sensitivity. As the particle size decreases, the shock sensitivity increases. Deflagration can also be initiated by shock. For coarse tetryl with a density of 1.65 grams per cubic centimeter in a 21 millimeter diameter plexiglas tube, the deflagration threshold pressure is 12.1 to 14 kilobar, as compared to 18 kilobar for detonation. Tetryl's sensitivity to shock initiation by an explosive bridge wire is dependent on particle size and crystal habit. The sensitivity decreases as packing density increases. In studies of tetryl's sensitivity to initiation by laser beams, no initiation occurred upon direct exposure to the beam. But if the tetryl sample was coated with a thin metal film, initiation was observed at a density of 1.08 grams per cubic centimeter. With higher density tetryl no initiation occurred.

(10) At a density of about 1.60 grams per cubic centimeter, the sand test indicates a brisance of 113 to 123 percent of TNT, the copper cylinder compression test indicates 117 to 125 percent, the lead block compression test indicates 112 percent, the plate dent test indicates 115 percent, and the fragmentation effect test indicates 121 percent. The ideal detonation velocity as a function of density is given by the equation:

$$D=5600+3225(p-1)$$

where D, the detonation velocity, is in units of meters per second and p, the density, is in grams per cubic centimeter. This equation yields slightly higher values than have been observed by other researchers. Low velocity detonation has been observed when coarse tetryl is weakly initiated. Below a certain diameter, which varies with particle size, low velocity detonation can be stable for lengths up to 25 charge diameters. Above this diameter low velocity detonation is stable for only distances of 2 to 4 charge diameters, at which point there is a transition to normal detonation velocity. Table 8-31 summarizes the dependence of transition diameter, minimum diameter for low velocity detonation, minimum diameter for normal detonation, and the approximate speed for low velocity detonation on particle size for 0.9 grams per cubic centimeter tetryl. Low velocity detonation is not affected by the initiating power of the detonator, provided the detonator is weak enough not to initiate normal detonation. For charge diameters between the minimum diameter for low velocity detonation and minimum diameter for normal detonation, even powerful initiators will produce only steady, low velocity detonation, provided the charge is of sufficient strength. Low velocity detonation is maximum at the transition diameter. This velocity is virtually independent of particle size and even type of explosive. TNT, PETN, RDX, and tetryl all have the same maximum low velocity detonation. Experiments with oil coated or crushed particles suggest that the main reaction in low velocity detonation is surface combustion. The power of tetryl by the ballistic pendulum test is 145 percent that of TNT, by the ballistic mortar test 126 to 132 percent of TNT, and by the Trauzl test 125 to 145 percent of TNT. The heat of detonation as a function of density is given by the equation:

$$Q=680+282p$$

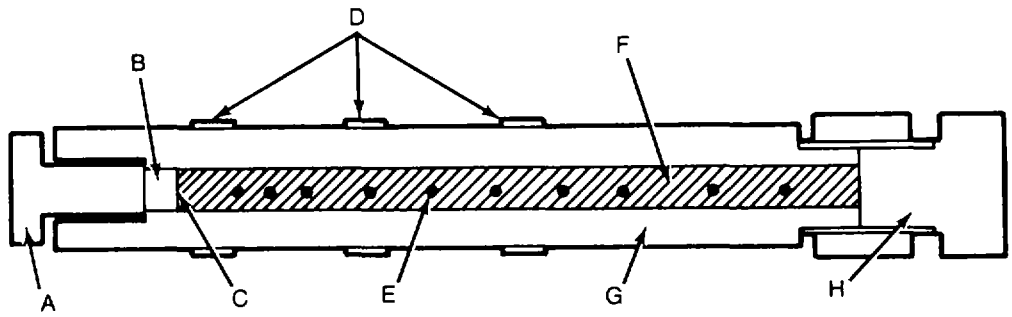
where Q is in units of calories per gram and p, the density, is in grams per cubic centimeter. The values given by the above equation fall short of the computed values for an ideal detonation. Point initiation studies with tetryl at a density of 1.51 grams per cubic centimeter indicate that the radius of curvature of the detonation front increases with charge length in the manner expected for spherical expansion of the front. The radius of curvature is also a function of the particle size and packing density of the explosive. The apparatus shown in figure 8-36 was used to study the deflagration to

detonation transfer in tetryl. After ignition, the length of the column before detonation occurs is determined by the markings on the tube fragments recovered. This result is checked with the ionization probe and strain gage records for consistency. The results for coarse tetryl with a particle size of 470 microns and fine tetryl with a particle size of 20 microns are plotted in figure 8-37. According to the graph, both fine and coarse tetryl show the same effects of compaction on predetonation column length, which is nearly constant at low density, with increasing values at 75 percent density. At a given density, the fine tetryl has a greater predetonation column length than the coarse, as well as longer relative time to detonation. In the experiments with tetryl, the ionization probes frequently failed to respond because the decomposition products formed shortly after ignition have such a high electrical resistance. Another unique characteristic of tetryl is that the onset of accelerated burning is located nearer to the onset of detonation than the ignition region. Both of these effects are attributed to the low temperature of decomposition of tetryl. The addition of 3 percent wax to a sample changes the initial low temperature decomposition to behavior typical of other explosives, with accelerated burning starting sooner. The burning rate of tetryl is not greatly affected by the initial temperature of the sample; the rate increasing by less than a factor of two for a temperature difference of 100°C. The burning rate decreases with additions of small amounts of water, and increases with increasing ambient pressure.

(11) Figure 8-38 shows the amount of gas evolved by tetryl as a function of temperature and time. The presence of picric acid tends to accelerate the evolution of gas, while trinitroanisole or trinitroaniline tend to slow the evolution of gas. Table 8-32 shows the composition of the gaseous products of tetryl decomposition.

Table 8-31. Low Velocity Detonation in Tetryl

Particle size in millimeters	Minimum diameter for low velocity detonation	Minimum diameter form normal detonation in millimeters	Transition diameter in millimeters	Minimum low velocity detonation in kilometers per second	Maximum low velocity detonation in kilometers per second
0.5	7	13	13	1.4	2.1
0.8	9	15	16	1.3	2.3
1.3	12	20	21	1.3	2.2



A - IGNITER BOLT
B - IGNITER
C - IGNITER/EXPLOSIVE INTERFACE
D - STRAIN GAGES
E - IONIZATION PROBE LOCATION
F - EXPLOSIVE CHARGE
G - TUBE
H - BOTTOM CLOSURE

INNER DIAMETER = 16.3MM

OUTER DIAMETER = 50.8MM

DISTANCE FROM IGNITER/EXPLOSIVE INTERFACE TO BOTTOM CLOSURE = 295.4MM

Figure 8-36. Deflagration to detonation transfer apparatus.

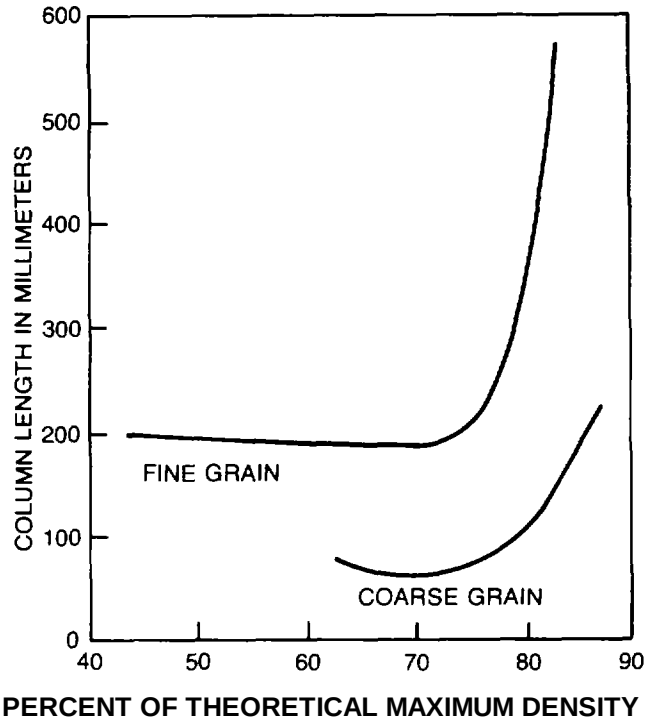


Figure 8-37. Effect of compaction on predetonation column length in tetryl.

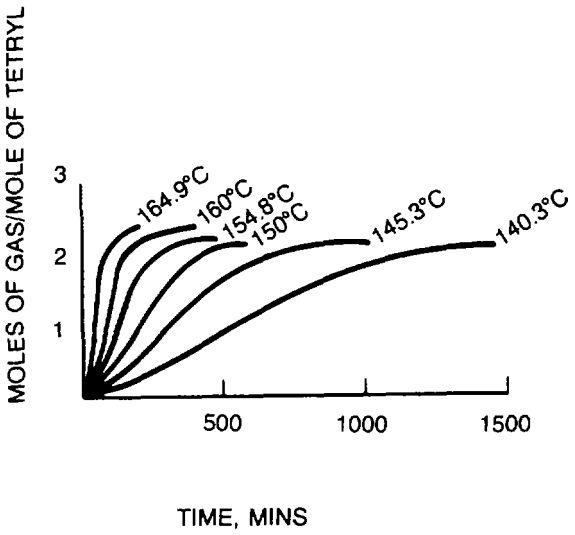


Figure 8-38. Kinetic gas-evolution curves in the decomposition of tetryl.

Table 8-32. Composition of Gaseous Products of Tetryl Decomposition

Time mins	Moles of gas per mole of tetryl	Composition of dry gas volume %				Composition of gas, moles per mole of tetryl				
		CO_2	CO	NO	N_2	CO_2	CO	NO_2	NO	N_2
221	0.650	23.6	10.6	4.3	61.5	0.134	0.060	0.016	0.024	0.348
1530	2.208	25.9	12.0	5.3	56.8	0.493	0.229	0.000	0.101	1.080
40	0.450	25.1	10.9	5.0	59.0	0.087	0.035	0.021	0.017	0.204
50	0.667	24.5	11.3	6.3	57.9	0.124	0.057	0.018	0.032	0.282
80	1.338	23.9	11.1	8.2	56.8	0.243	0.113	0.031	0.084	0.578
110	1.808	24.3	10.8	8.1	56.8	0.358	0.158	-	0.118	0.838
140	2.010	25.2	11.5	8.5	54.8	0.420	0.193	0.016	0.143	0.925
200	2.149	25.1	11.8	8.6	54.5	0.448	0.210	0.004	0.153	0.972
422	2.304	25.7	12.1	8.2	54.0	0.491	0.231	0.001	0.156	1.030
1440	2.674	27.8	13.4	8.4	50.4	0.624	0.302	0	0.190	0.130
40	1.950	24.5	11.6	8.8	55.1	0.397	0.188	0.023	0.142	0.892
382	2.572	27.7	12.7	9.6	50.0	0.584	0.268	0.003	0.202	1.060

Table 8-33 shows the composition of the condensed phase as a function of time for tetryl that has been heated at 160°C.

Table 8-33. Composition of Condensed Phase Tetryl

Time mins	Weight of residue as % of initial quantity of tetryl	Moles per mole of tetryl			
		Tetryl	2, 4, 6-trinitroanisole	Picric Acid	N-methyl-2, 4, 6-trinitroanalline
25	95.6	0.832	0.073	0.037	0.030
45	90.0		0.195		0.034
55	86.9	0.494	0.265	0.094	0.045
70	83.8		0.295	0.113	
90	80.5	0.227	0.412	0.131	0.072
111	78.2		0.503		
145	75.9	0.029	0.525	0.160	0.065
300	74.2	0.019	0.478	0.204	0.047
400	73.2		0.463		
1440	69.0	0	0.110	0.524	0.031

The heat of reaction for the slow decomposition of tetryl is 328 to 341 calories per gram. Vacuum stability tests show tetryl to be less stable than TNT. The DTA curve for tetryl is shown in figure 8-39 and the TGA curve is shown in figure 8-40. Ammunition that has been loaded with tetryl cannot be stored at temperatures greater than 125°. This is specifically why the United States has discontinued the use of this explosive. Tetryl corrodes steel heavily. Slight corrosion is reported for iron, zinc, zinc plated steel, tin plated steel, parkerized steel, brass, and monel metal. Tetryl does not react with copper, tin, nickel, lead, copper plated steel, bronze, stainless steel, cadmium, aluminum, silver, and titanium. Tetryl frequently is used with one to two percent of a binding agent or lubricant, such as graphite, stearic acid, or magnesium stearate; and has been found to be compatible with such materials as well as black powder.

8-4. Nitroaromatics. Compounds in this class are prepared by C-type nitration in which a nitrogroup is attached to a carbon atom of the compound being nitrated.

a. Ammonium Picrate.

(1) This explosive is also known as ammonium 2,4,6-trinitrophenolate, explosive D, and Dunnite. The compound (figure 8-41) has a nitrogen content of 22.77 percent, an oxygen balance to C02 of-52 percent, a maximum crystal density of 1.717 grams per cubic centimeter, a nominal density of 1.63 grams per cubic centimeter, a melting point with decomposition of about 280°C and a molecular weight of 246. Ammonium picrate exists in a stable form as yellow, monoclinic crystals and a meta stable form as red, orthorhombic crystals. The unit cell dimensions are a =13.45 Angstroms, b =19.74 Angstroms, and c =7.12 Angstroms. The compound manufactured for military use is yellow to orange in color. Table 8-34 lists the density of ammonium picrate as a function of loading pressure.

Table 8-34. Density of Ammonium Picrate

Pressure in kilopascals	Pressure in pounds per square inch	Density in grams per cubic centimeter
20,685	3,000	1.33
34,475	5,000	1.41
68,950	10,000	1.47
82,740	12,000	1.49
103,425	15,000	1.51
137,900	20,000	1.53
344,750	50,000	1.59
689,500	100,000	1.64

The refractive index at 20°C is: alpha, 1.508; beta, 1.870; and gamma, 1.907. The heat of combustion of ammonium picrate at constant pressure is 2,745 calories per gram, from which is derived a heat of formation value of 95.82 kilogram-calories per mole. The heat of explosion is 706 calories per gram. Table 8-35 lists the solubility of ammonium picrate in various solvents as a function of temperature.

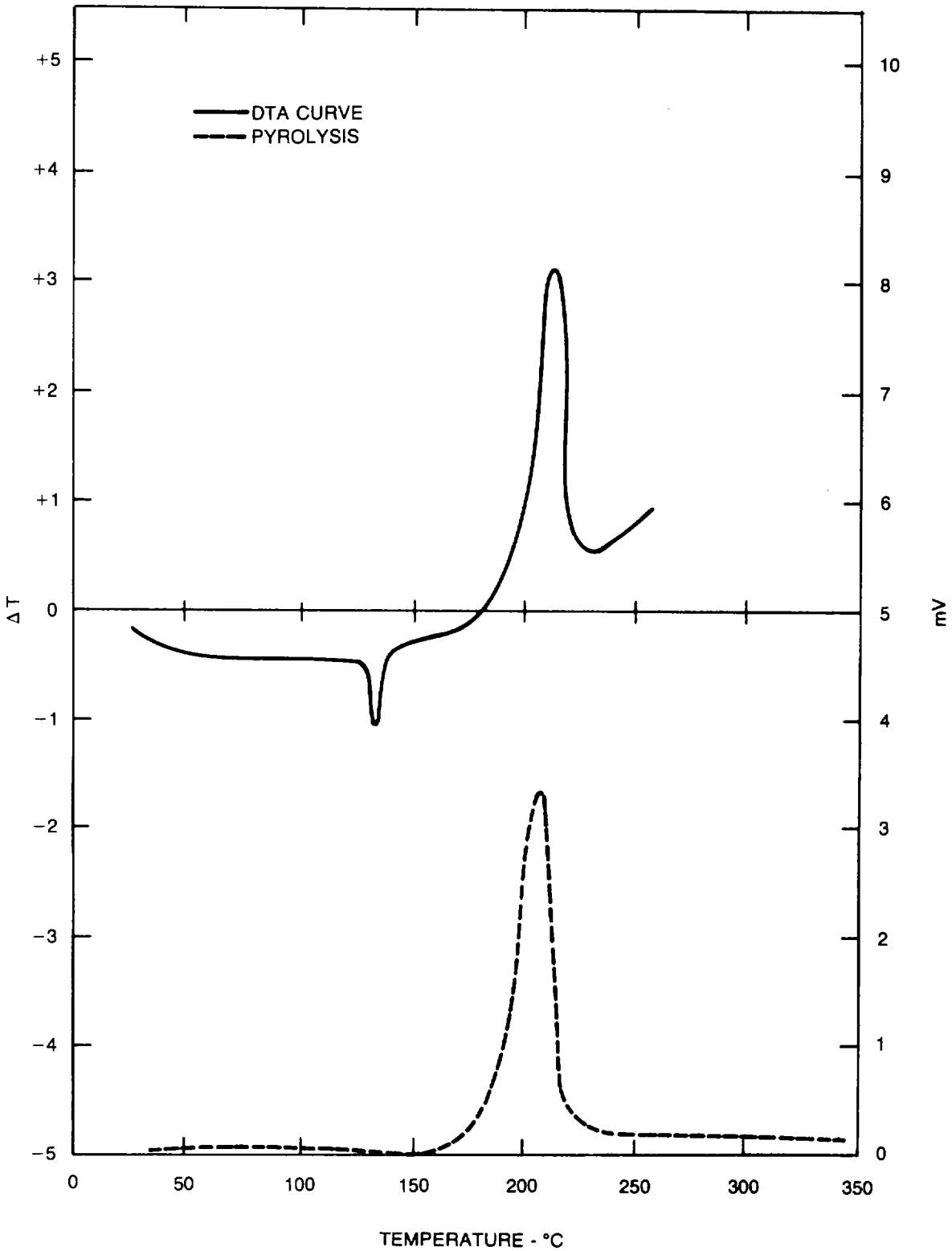


Figure 8-39. DTA curve for tetryl.

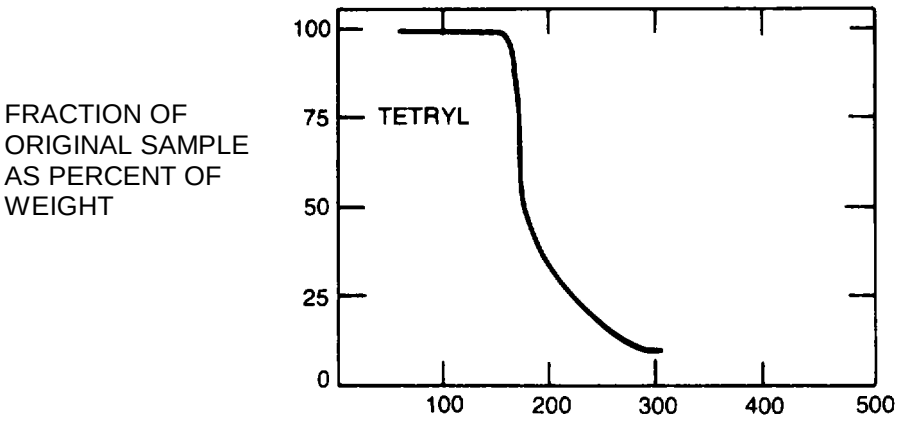


Figure 8-40. TGA curve for tetryl.

Table 8-35. Solubility of Ammonium Picrate

Solvent	Solubility in grams per 100 grams of solvent						
	0°C	10°C	20°C	30°C	50°C	80°C	100°C
Water	-	0.70	102	-	-	-	75
Ethanol	0.51	0.69	0.86	1.05	1.89	3.62	-
Ethyl acetate	0.29	0.30	0.34	0.38	0.45	0.56	-
Acetone	-	-	-	2.85	-	-	-
Octyl alcohol	-	-	0.2	-	-	-	-
	-	-	at	-	-	-	-
	-	-	25°C	-	-	-	-

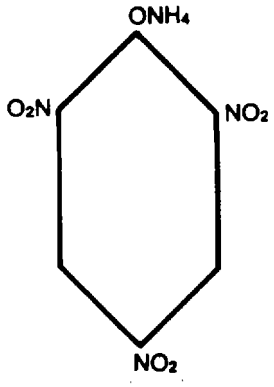


Figure 8-41. Structural formula for ammonium picrate.

In ethanol, ammonium picrate dissolves very slowly and slow separation occurs when the solution is left standing. The solubility in ether is very slight. Ammonium picrate, because of an extreme insensitivity to shock, is used in armor piercing projectiles. The compound is also used in jet assisted takeoff units for aircraft.

(2) Chemically, ammonium picrate is not very reactive. Decomposition by alkalies yields picric acid and ammonia. This reaction is the basis of one of the methods for determining the purity of the material. When maintained at the melting point, ammonium picrate decomposes to the same products. At 0°C an equimolecular amount of ammonia is absorbed, but at 26°C this is lost by volatilization.

(3) The manufacture of ammonium picrate is relatively simple. Picric acid, which is only partially soluble in water, is suspended in hot water and neutralized by the addition of gaseous or aqueous ammonia. The picrate, which is more soluble in water, is formed and immediately goes into solution. The reaction is slightly exothermic. On cooling the solution, the ammonium picrate separates out. If a marked excess of ammonia is used, the red form is obtained so care must be taken to avoid this and obtain the yellow form. The yellow form has a higher bulk density than the red and can be pressed better. The separated crystals are washed with cold water to remove any free ammonia present and then dried.

(4) The specifications for ammonium picrate cover one grade of material representing two classes with respect to granulation. Class 1 material, which is the coarser of the two classes, is intended for use in the press-loading of shells, while class 2 is used for the manufacture of picratol and other compositions. The requirements are as follows:

	Class1	Class 2
Surface moisture and volatile content (%), maximum:	0.10	
Total moisture content (%), maximum:	-	0.2
Ammonium picrate purity (%), minimum:	99	99
Sulfates (as sulfuric acid) (%), maximum:	0.10	0.10
Chloroform insoluble impurities (%), maximum:	0.10	-
Water insoluble material (%), maximum:	0.10	0.10
Irritant contaminants as parts chlorine per million, maximum:	50	-
Ash (%), maximum:	0.1	0.1
Acidity and alkalinity (as picric acid or ammonia (%), maximum:	0.025	0.025
Color	Yellow to orange	Yellow to
Granulation (US standard sieves)		
Percent through No. 12 sieve, minimum	99.9	-
Percent through No. 40 sieve, minimum	-	99.5
Percent retained on No. 70 sieve, minimum	60	-
Percent retained on No. 70 sieve, maximum	-	20
Percent through No. 200 sieve, maximum	5	-

The picric acid used to make class 2 ammonium picrate shall be made by the nitration of phenol and shall contain no material salvaged from trimmings or from loading operations. Class 2 ammonium picrate shall contain no reworked ammonium picrate made by way of any process other than the phenol nitration process. The irritant contaminants requirement is not applicable to ammonium picrate made from picric acid produced by the nitration of phenol. The color requirement is intended to cover the unavoidable presence of a small amount of the red form of ammonium picrate in admixture with the yellow form. The requirement with respect to irritant contaminants represents a control of the purity of picric acid used in manufacture when this is made by the dinitrochlorbenzene process. The chloroform soluble matter requirement also represents a control of the nature of impurities present in picric acid manufactured by a process other than the nitration of phenol.

(5) Ammonium picrate is distinctly less sensitive to impact than TNT and is unaffected by the steel shoe in the pendulum friction test. A slightly greater sensitivity is indicated by the rifle bullet impact test with three partially burned samples in ten trials. This is attributed to the lower temperature required for explosion for ammonium picrate, 318°C in the five second test, as opposed to 457°C for TNT. The time to explosion as a function of temperature is shown in table 8-36.

Table 8-36. Ammonium Picrate Explosion Temperature

Time in seconds	Temperature in degrees centigrade
0.1	405
1	367
5	318
10	314
15	299
20	295

The low degree of sensitivity of ammonium picrate to impact is paralleled by a relative insensitivity to initiation. In the sand test, ammonium picrate is not detonated completely by either lead azide or mercury fulminate. A booster charge of 0.06 gram of tetryl is required for complete detonation. In this test, a minimum charge of 0.28 gram of diazodinitrophenol detonates ammonium picrate but a charge of only 0.15 gram is required for the detonation of TNT. The minimum charge of mercury fulminate required to initiate 0.4 grams of ammonium

picrate loaded at about 200 atmospheres of pressure is 0.85 grams versus 0.26 grams of mercury fulminate necessary to initiate 0.4 grams of TNT. Moisture has a marked effect on the sensitivity of ammonium picrate to initiation. The presence of 0.5, 1.0, and 2.0 percent of moisture requires increases in the minimum detonating charge of tetryl to 0.09, 0.11, and 0.14 gram, respectively. Storage of either the yellow or red form at 50°C for two years causes such an increase in sensitivity that initiation by mercury fulminate alone is possible. Subsequent storage of the yellow form at magazine temperatures for two years causes desensitization to such an extent that a booster charge to tetryl is required for complete detonation and four years of such storage is required for return to the original condition of insensitivity. Storage at 500C has the same effect on the sensitivity of red ammonium picrate but subsequent storage at magazine temperatures for four years merely increases the minimum detonating charge of mercury fulminate from 0.23 to 0.29 gram. The changes in sensitivity are not accompanied by any change in brisance or in color. In an electrostatic sensitivity test for material that passes through a 100 mesh sieve, an energy of 6.0 joules was required for confined material and 0.025 joules for unconfined material. Ammonium picrate which has been pressed into and removed from projectiles or other ammo is much more sensitive to shock than new or unused material. Therefore, reclaimed material should not be pressed or loaded into ammo items until after recrystallization.

(6) In the sand test, 37.5 grams to 39.5 grams of sand are crushed, which indicates a brisance of 78 to 82.5 percent of TNT. The plate dent test indicates a brisance of 91 percent of TNT for a charge of ammonium picrate with a density of 1.50 grams per cubic centimeter. Fragmentation tests indicate a brisance of 91 percent, 96 percent and 99 percent of TNT for charges that have been pressed to density values of 1.50, 1.53, and 1.55, respectively. The approximate velocity of detonation as a function of density is given by the equation:

$$V = 960 + 3800d$$

where V is in meters per second and d, the density, is in grams per cubic centimeter. A charge diameter of 2.54 centimeters was used to determine the above equation. The critical diameter for a sample with density of 1.65 grams per cubic centimeter is greater than 25.4 millimeters. When exploded adiabatically at constant volume, ammonium picrate produces a pressure of 8956 kilograms per square centimeter when pressed to a density of 1.5 grams per cubic centimeter, and 9553 kilograms per square centimeter when pressed to a density of 1.6 grams per cubic centimeter. These values are 113 percent of the corresponding values for TNT. Although the heat of explosion of ammonium picrate is only 86 percent that of TNT, the ballistic pendulum test indicates a power of 98 percent of TNT. This combination of brisance and power, almost equal to those of TNT, together with relative insensitivity, has made ammonium picrate suitable for use in armor piercing projectiles. However, the impracticality of melt-loading ammonium picrate has led to partial replacement by picratol, which can be melt-loaded. When ignited in an unconfined state, ammonium picrate burns slowly without detonation emitting dense, black smoke. However, when confined and heated to the ignition temperature, an explosion occurs. Complete detonation produces a dense, black cloud of smoke with sooty deposits and an odor of ammonia. When incomplete detonation occurs, yellow smoke is produced along with unburned ammonium picrate particles.

(7) Ammonium picrate is of a very high order of stability. In the 100°C heat test, 0.1 percent is lost in the first 48 hours and 0.1 percent in the second 48 hours. No explosions occur in 100 hours. In the 130°C heat test there is no acidity or explosion in 300 minutes. The vacuum stability test at 100°C produced 0.2 cubic centimeters of gas in 40 hours, at 120°C, 0.4 cubic centimeters of gas are produced, and at 150°C, 0.4 cubic centimeters of gas are produced. The material has been found to withstand storage at ordinary temperatures for a period of twenty years with no evidence of deterioration, and at 50°C for more than five years without marked deterioration. Moisture increases ammonium picrate's reactivity with metals such as lead, potassium, copper, and iron. The compounds produced are extremely sensitive. This reactivity requires that all projectiles loaded with this material have contact areas covered with acid proof paint. At 100°C ammonium picrate is compatible with TNT or black powder but undergoes reactions with nitroglycerin, nitrocellulose, PETN, or tetryl. Figure 8-42 shows the DTA curve for ammonium picrate.

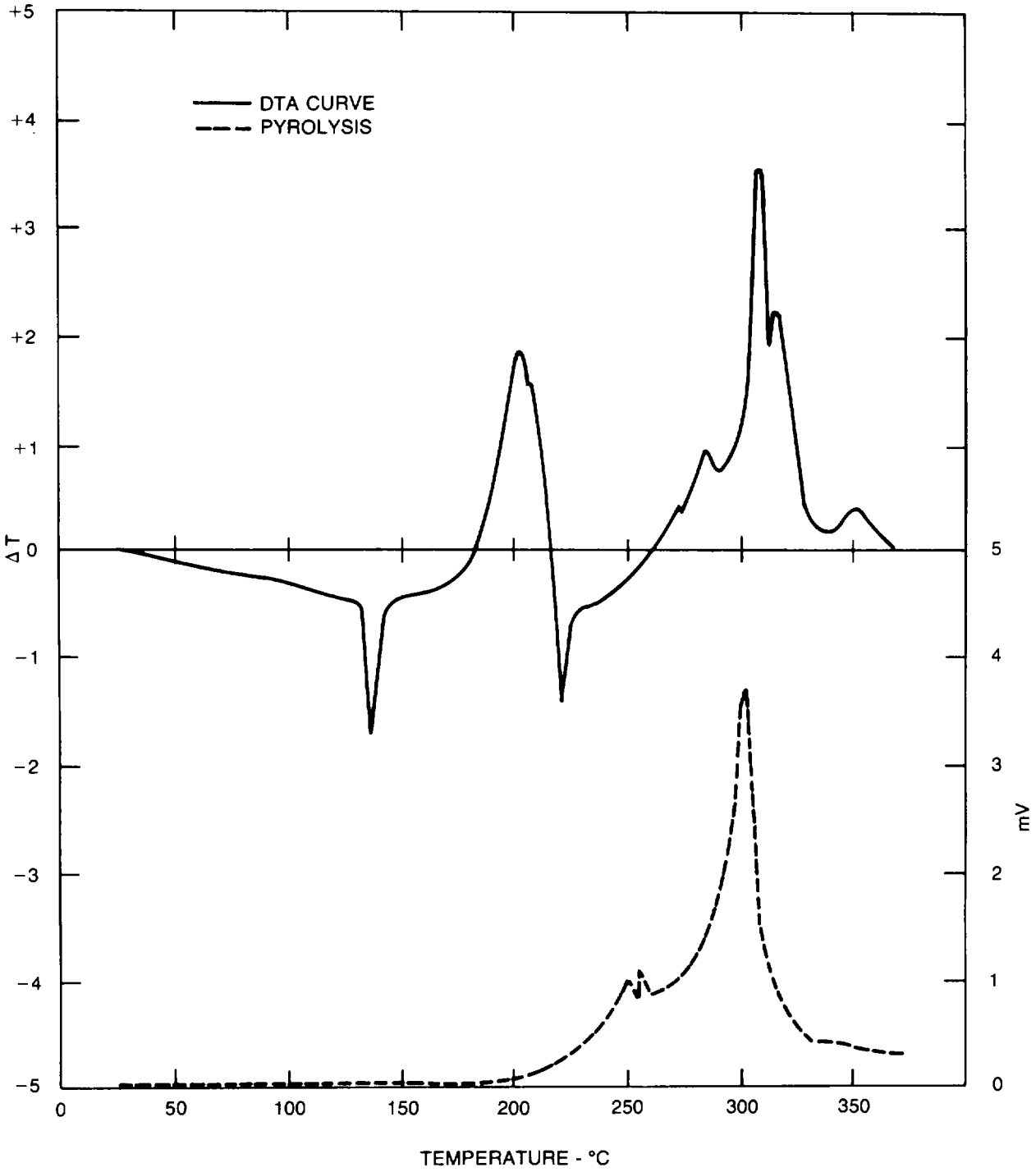


Figure 8-42. DTA curve for ammonium picrate.

b. 1,3-Diamino-2,4,6-Trinitrobenzene (DA TB).

(1) This explosive is also known as 2,4,6trinitro-1,3-diaminobenzene; 2,4,6-trinitro-7,3benzenediamine trinitro-m-phenylenediamine; or 2,4,6-trinitro-1 ,3-diaminobenzol and may be referred to as DATNB. The compound (figure 8-43) is a yellow, crystalline solid with a nitrogen content of 28.81 percent, a melting point of 2860C to 301°C with decomposition, and a molecular weight of 243.14. Two polymorphs of DATB have been identified. Form I, which is stable to 2170C, has two molecules per unit cell and unit cell lengths of a=7.30 Angstroms, b=5.20 Angstroms, c = 1 1.63 Angstroms. Form II has four molecules per unit cell and unit cell lengths of a=7.76 Angstroms, b =9.04 Angstroms, c = 12.84 Angstroms. The maximum density of form I is 1.837 grams per cubic centimeter and the density of form II is 1.815 grams per cubic centimeter. The nominal density of DATB is 1.79 grams per cubic centimeter. DATB is slightly soluble in acetic acid and only very slightly soluble in other solvents. The vapor pressure is given by the equation:

$$\log p = 12.75 - 7492/T(°C)$$

for 92.8°C < T < 176.8°C

The heat of formation is 97.1 to -1 19 calories per gram, the heat of combustion is-7115 kilocalories per mole, the heat of detonation with liquid water was experimentally determined as 980 calories per gram and with gaseous water, 910 calories per gram. The computed maximum values for the heat of detonation are 1260 calories per gram and 1150 calories per gram for gaseous and liquid water, respectively. The specific heat is given by the equation:

$$Cp = 0.20 + (1.11 \times 10\text{-}3)T - (1.81 \times 10^{-6})T2$$ for 47°C < T < 200°C

The heat of sublimation is 138 calories per gram. DATB can be used as a pressed explosive or as a ballistic modifier in some rocket propellents.

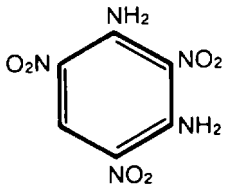


Figure 8-43. Structural formula for DATB.

(2) DATB can be prepared by nitrating m-dichlorobenzene to 2,4,6-trinitro-1,3dichlorobenzene and aminating in methanol solutions. Another method of preparation is by the amination of 2,4,6-trinitro-3-aminoanisole. In a third method of preparation phosphorous oxytrichloride and dipyridinium styphnate are reacted directly at steam bath temperature and a suspension of the resulting 2,4,6-trinitro1,3-dichlorobenzene in methanol is treated with gaseous ammonia. Impact sensitivity is 200 percent that of TNT. Table 8-37 shows the gap test results for DATB.

Table 8-37. Gap Test Results for DATB

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.775	3.5	3.28
	1.233	33	5.18
LANL small scale gap test	1.801 (hot pressed)	2.0	0.36
	1.714 (pressed)	6.7	1.27
LANL large scale gap test	1.786 (pressed)	2.8	41.68
	1.705 (pressed)	7.2	45.36
	0.81 (bulk)	56	49.3
PX gap test	1.781	3.2	17.86
	1.446	21.3	19.94

(3) The detonation velocity is given by the equation:

$$D = 2.480 + 2.852p$$

where D is in kilometers per second and p, the density, is in grams per cubic centimeter. The failure diameter of unconfined DATB at a density of 1.816 grams per cubic centimeter is 5.3 millimeters. The detonation pressure is 251 and 259 kilobars for samples with densities of 1.780 and 1.790 grams per cubic centimeter, respectively. The plate dent test indicates a brisance of 120 percent of TNT.

(4) In the vacuum stability test, less than 0.03 cubic centimeters of gas are evolved in 48 hours at 120°C. In the LLNL reactivity test, less than 0.03 cubic centimeters of gas are evolved per 0.25 grams of sample in 22 hours at 120°C. Figure 8-44 shows the DTA curve for DATB.

c. 2,2'4,4',6,6'-Hexanitroazobenzene (HNAB).

(1) This explosive is also known as bis (2,4,6trinitrophenyl)-diazene. HNAB forms blood red prisms when crystallized from nitrobenzene, glacial acetic acid, or concentrated nitric acid. The compound (figure 8-45) has a melting point of 215°C to 216°C, a molecular weight of 452, and a density of 1.79 grams per cubic centimeter. HNAB has a heat of formation of-58 to-67.9 calories per mole and a heat of detonation of 1.47 kilocalories per gram for liquid water and 1.42 kilocalories per gram for gaseous water. The specific heat is 0.3 calories per gram per degree centigrade. Table 8-38 shows the gap test results for HNAB.

Table 8-38. Gap Test Results for HNAB

	Density in grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.774	-	6.38
	1.383	-	12.04
LANL small scale gap test	1.601 pressed	-	5.6

(2) One method of obtaining HNAB is to treat picryl chloride, $(NO_2)_3.C_6H_2.Cl$, with hydrazine, $H_2N.NH_2$, to obtain hexanitrohydrazobenzene. The hexanitrohydrazobenzene is then oxidized by nitric acid or nitrogen oxide gas in a glacial acetic acid solution to HNAB. The nitrogen oxide gas is obtained from the reaction of nitric acid and As_20_3. Another method of obtaining HNAB also involves two steps. The first step is to suspend a mixture of dinitrochlorobenzene, $(NO_2)_2.C_6H_3.Cl$, with hydrazine in hot water that contains sodium or calcium carbonate to form tetranitrohydrazobenzene, $(NO_2)_2.C_6H_3.NH.HN.C_6H_3(NO_2)_2$. The second step is to treat the tetranitrohydrazobenzene with concentrated nitric acid. The nitric acid introduces the two required N02 groups and also oxidizes the -NH.HNgroup to an -N: Ngroup to form HNAB.

(3) HNAB is a very powerful and brisant high explosive. At a density of 1.77 grams per cubic centimeter, the detonation velocity is 7250 meters per second. Power, by the Trauzl test, is 123 percent of TNT. The DTA curve for HNAB is shown in figure 8-46.

d. Hexanitrostilbene (HNS).

(1) This-explosive is also known as hexanitrodiphenyjethylene or 1,2 bis-(2,4,6-trinitrophenyl)ethylene or 1,1'-(1,2-ethenediyl) bis-(2,4,6trinitrobenzene). The compound (figure 8-47) forms yellow needles when crystallized from nitrobenzene. HNS has a nitrogen content of 18.67 percent, a molecular weight of 450.24, and a melting point of 316°C. The theoretical maximum density of type I HNS is 1.740 grams per cubic centimeter with a nominal density of 1.72 grams per cubic centimeter. The crystals are orthorhombic with unit cell dimensions of a=22.13 Angstroms, b =5.57 Angstroms, c = 14.67 Angstroms. At the melting point decomposition and explosions occur. The heat of formation is 13.9 to -18.7 kilocalories per mole, the heat of sublimation is 94.9 calories per gram, the heat of detonation with liquid water is 1.42 kilocalories per gram, and the heat of detonation with gaseous water is 1.36 kilocalories per gram. The specific heat is given by the equation:

$$Cp = 0.201 + (1.27 \times 10^{-3})T - (2.39 \times 10^{-6})T2 \text{ for } 47°C < T < 220°C$$

where Cp is in calories per gram per degree centigrade.

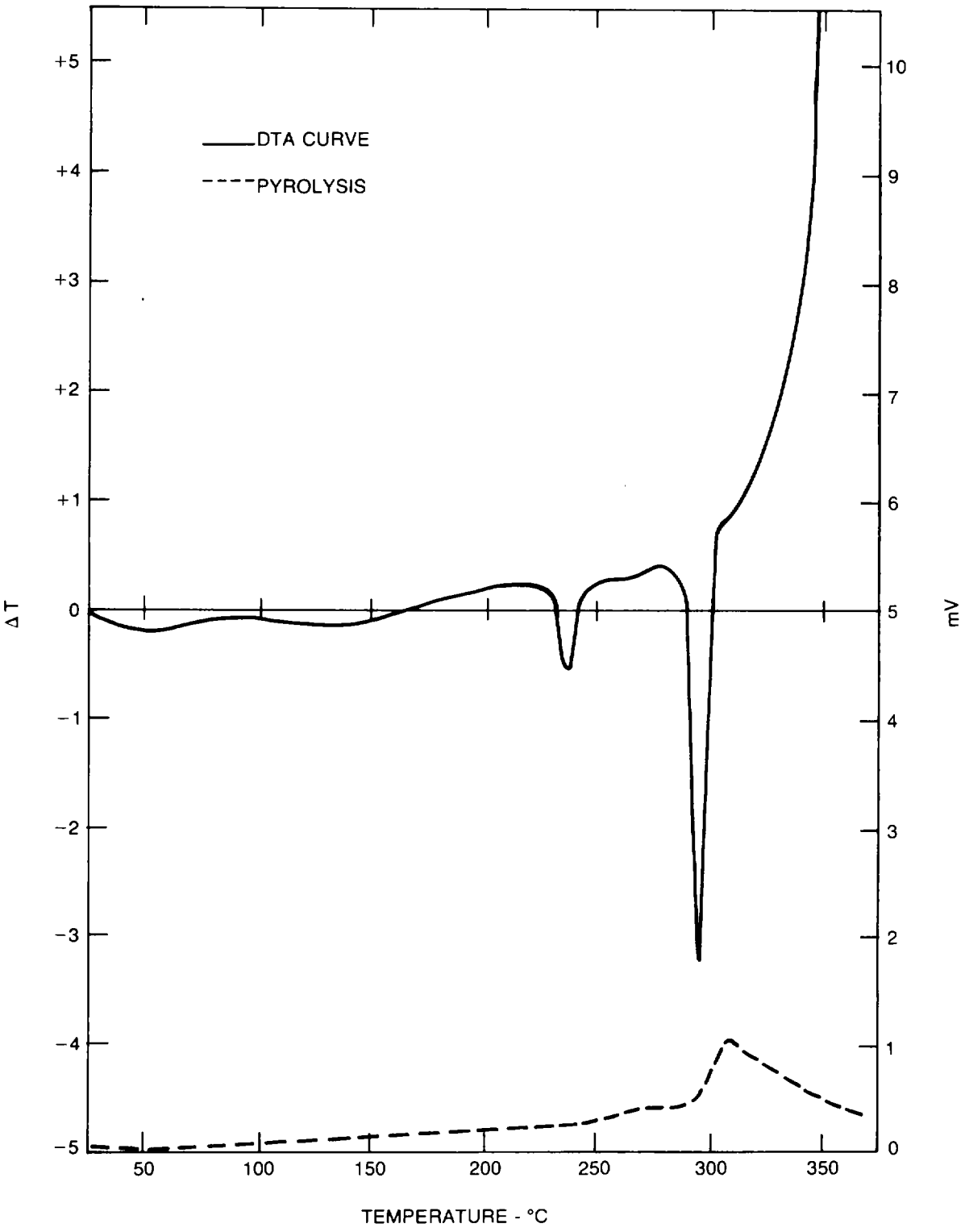


Figure 8-44. DTA curve for DATB.

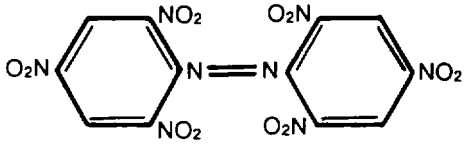


Figure 8-45. Structural formula for HNAB.

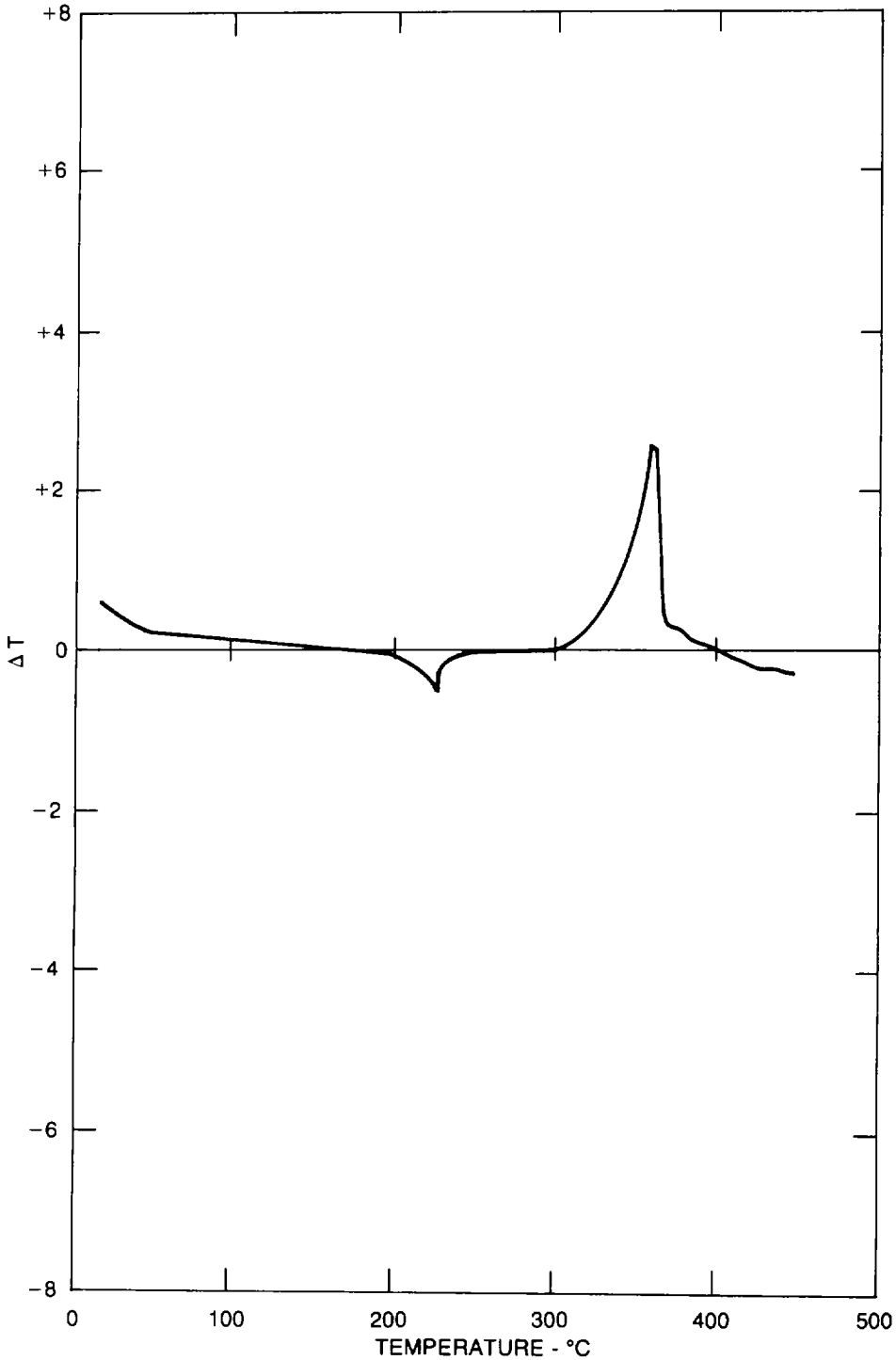


Figure 8-46. DTA curve for HNAB.

HNS is soluble in dimethyl formamide and slightly soluble in hot acetone, methylethyl ketone, and glacial acetic acid. HNS is used as a heat resistant booster explosive and has excellent properties for use in PBXs and mild detonating fuse end couplers and end boosters.

(2) HNS can be prepared from 2,4,6trinitrobenzyl chloride by heating on a steam bath with methanol containing potassium hydroxide. HNS has a uniquely small critical diameter of about 0.5 millimeters (0.020 inch), is practically insensitive to electrostatic spark, is less sensitive to impact than tetryl, and is radiation resistant.

(3) Two types of HNS are manufactured, as shown in table 8-39.

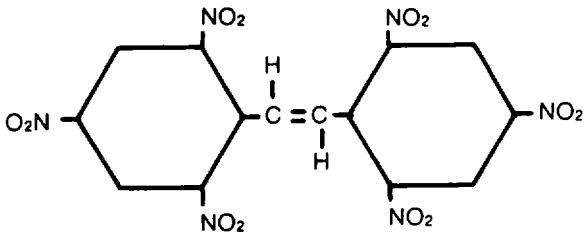


Figure 8-47. Structural formula for HNS.

Table 8-39. Properties of HNS

Property	Type I	Type II
Melting point, °C with decomposition	316	319
Particle size in microns	1-5	100-300
Bulk density in grams per cubic centimeter	0.32-0.45	0.45-1.0
Differential thermal analysis, onset of exotherm	315°C	325°C
Electrostatic spark sensitivity, fires above, in micro farads	0.001 at 8kv	0.0001 at 17kv
Friction sensitivity in kilograms per centimeter	440	440
Impact sensitivity in centimeters, Naval Ordnance Laboratory machine	44	61
Vacuum stability at 260°C in cubic centimeters per gram per hour:		
1st 20 minutes	1.8	0.3
Additional two hours	0.6	0.2
At 280°C	2.7	2.7
Velocity of detonation in meters per second at a density of 1.70 grams per cubic centimeter	7000	7000
Autoignition point	325°C	325°C
Decomposition rate at 260°C	0.1%/hour	0.1%/hour
Heat of combustion, calories per gram	3451	3451
Mean firing voltage for an explosive bridge wire with a one microfarad capacitor	12,950 at 0.9 grams per cubic centimeter	12,950 at 0.9 grams per cubic centimeter
Vapor pressure	2.9×10^{-8} torr at 160°C	2.9×10^{-8} torr 160°C

(4) HNS is half as sensitive to impact as TNT.

Gap test results for HNS are shown in table 8-40.

Table 8-40. Gap Test Results for HNS

	Density in grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test			
HNS I	1.694	2.6	5.18
	1.122	35.5	7.06
HNS II	1.725	0.9	5.46
	1.644	-	7.52
	1.322	24	9.53
LANL small scale gap test			
HNS I	1.669	4.1	5.28
	1.566	10	5.84
	1.376	20.9	6.71
	1.840 (pressed)	2.1	2.31

(5) At a density of 1.70 grams per cubic centimeter, the velocity of detonation is 7,000 meters per second and the detonation pressure is 262 kilobars. The plate dent test indicates a power of 120 percent of TNT.

(6) In the 100°C heat test, HNS loses less than 1 percent weight in 48 hours. Less than one cubic centimeter of gas is evolved in the 100°C vacuum stability test. Figures 8-48 and 8-49 show the DTA and TGA curve for HNS, respectively.

e. 1,3,5Triamino-2, 4,6Trinitrobenzene (TA TB).

(1) This explosive is also known as 2,4,6trinitro-1,3,5-benzenetriamine and may be referred to as TATNB. TATB (figure 8-50) has a nitrogen content of 32.56 percent, an oxygen balance to C02 of-55.78 percent, and a molecular weight of 258.18. TATB is yellow but exposure to sunlight or ultraviolet light causes a green coloration which, with prolonged exposure, turns brown. The compound has a theoretical maximum density of 1.937 grams per cubic centimeter and a nominal density of 1.88 grams per cubic centimeter. An instantaneous hot bar decomposition temperature of 450°C to 451 °C was reported with rapid thermal decomposition above 320°C. The structure of the crystalline lattice of TATB (figure 8-51) contains many unusual features. Some of these are the extremely long C-C bonds in the benzene ring, the very short C-N bonds, amino bonds, and the six furcated hydrogen bonds. Evidence of a strong intermolecular interaction, hydrogen bonds, in TATB is indicated by the lack of an observable melting point and very low solubility. The intermolecular network results in a graphite-like lattice structure with the resulting properties of lubricity and intercalaction. Physical properties of the triclinic unit cell, which consists of two molecules, are a=9.010 Angstroms, b=9.028 Angstroms, c=6.812 Angstroms, and alpha=108.590, beta=91.82°, and gamma= 119.97°. Continuous monitoring of the cell constants of TATB between 214°K and 3770K allowed for the calculation of a volume change of +5.1 percent for this molecular system. Expansion of the pure material is almost exclusively a function of a 4 percent linear increase in the c axis, which is the perpendicular distance between sheets of hydrogen-bonded TATB molecules. The solubility of TATB is greater than 20 percent by weight per volume of solution in super acids such as concentrated sulfuric acid, chlorosulfonic acid, fluorosulfonic acid, and trifluoromethane sulfuric acid. Table 8-41 lists the solubility of TATB in various solvents.

Table 8-41. Solubility of TATB in Various Solvents

Solvent	Solubility, in parts per million
Methanesulfonic acid	820
Hexamethylphosphortriamide	150
Ethanesulfonic acid	120
DMSO	70
Hexafluoroacetone sesquihydrate	68
N-methyl-2-pyrrolidinone	58
N,N-dimethylacetamide	33
DMF	27
Tetramethylurea	26
Dimethyl methylphosphonate	22
N,N-dimethylpropionamide	16
Bis(dimethylamino)phosphochloridate	14
Gamma butyrolacetone	14
Concentrated nitric acid	14

Table 8-41. Solubility of TATB in Various Solvents (Cont)

Solvent	Solubility, in parts per million
3-Methylsulfolane	13
Pyridine	12
Trimethylphosphate	11
Dimethylcyanamide, vinyl sulfone	8
Methyl dichlorophosphate	7
N-methylformamide	6
Methyl methanesulfonate	5
Trimethylphosphite	4
Acetone	3
Dimethyl carbamoyl chloride	3
Acetonitrile	3
Acetic anhydride	3
Trifluoroacetic acid	3
Acetic acid	1
Hexamethyldisilazane	less than 1
Trifluoroacetic anhydride	less than 1
Hexafluorobenzene	less than 1
Pentafluoropyridine	less than 1
Perfluoro-2-butyltetrahydrofuran	less than 1
Basic solvents:	
Tetramethylguanidine	485
Bu_4NOH, 25% in methanol	390
N,N,N',N'-Tetramethylglycinamide	67

At 131.40C and 171.30C TATB has vapor pressures of 10-7 torr and 10-5 torr, respectively. At 344,750 and 441,280 kilopascals (50,000 and 64,000 pounds per square inch) the loading density of TATB is 1.80 and 1.89 grams per cubic centimeter, respectively. Thermochemical characteristics include a heat of combustion of 735.9 kilocalories per mole, a heat of detonation with gaseous water at 1.87 grams per cubic centimeter of 1018 calories per gram, a heat of detonation with liquid water of 2831 calories per gram, and a heat of formation of -33.46 to -36.85 kilocalories per mole. The heat of sublimation is 155.7 calories per gram and the heat of reaction during self-heating is 600 calories per gram. The heat capacity as a function of temperature is given by the equation:

$$\text{Specific heat} = 0.215 + (1.324 \times 10^{-3})\,T - (2 \times 10^{-6})T^2$$

for $0°C < T < 300°C$

The effects of gamma radiation are shown in table 8-42.

Table 8-42. Effects of Gamma Radiation on TATB

Amount of cobalt 60 radiation R	Density before irradiation in grams per cubic centimeter	Density of kv irradiation in grams per cubic centimeter	Detonation velocity in meters per second	Detonation pressure in kilobars	Explosion temperature in C
Control	1.84	-	7,510	260	403
1.0×10^7	1.84	1.84	7,520	260	394
9.0×10^7	1.85	1.84	7,525	261	370
7.4×10^8	1.82	1.81	7,435	250	345

TATB is suitable for use in plastic explosives and in explosives mixtures with TNT that can be cast. The major military use is in special applications in warheads of high speed guided missiles. In this application energy is sacrificed but handling safety is gained because the main charge remains inert under the service environments of high velocity impact and fire.

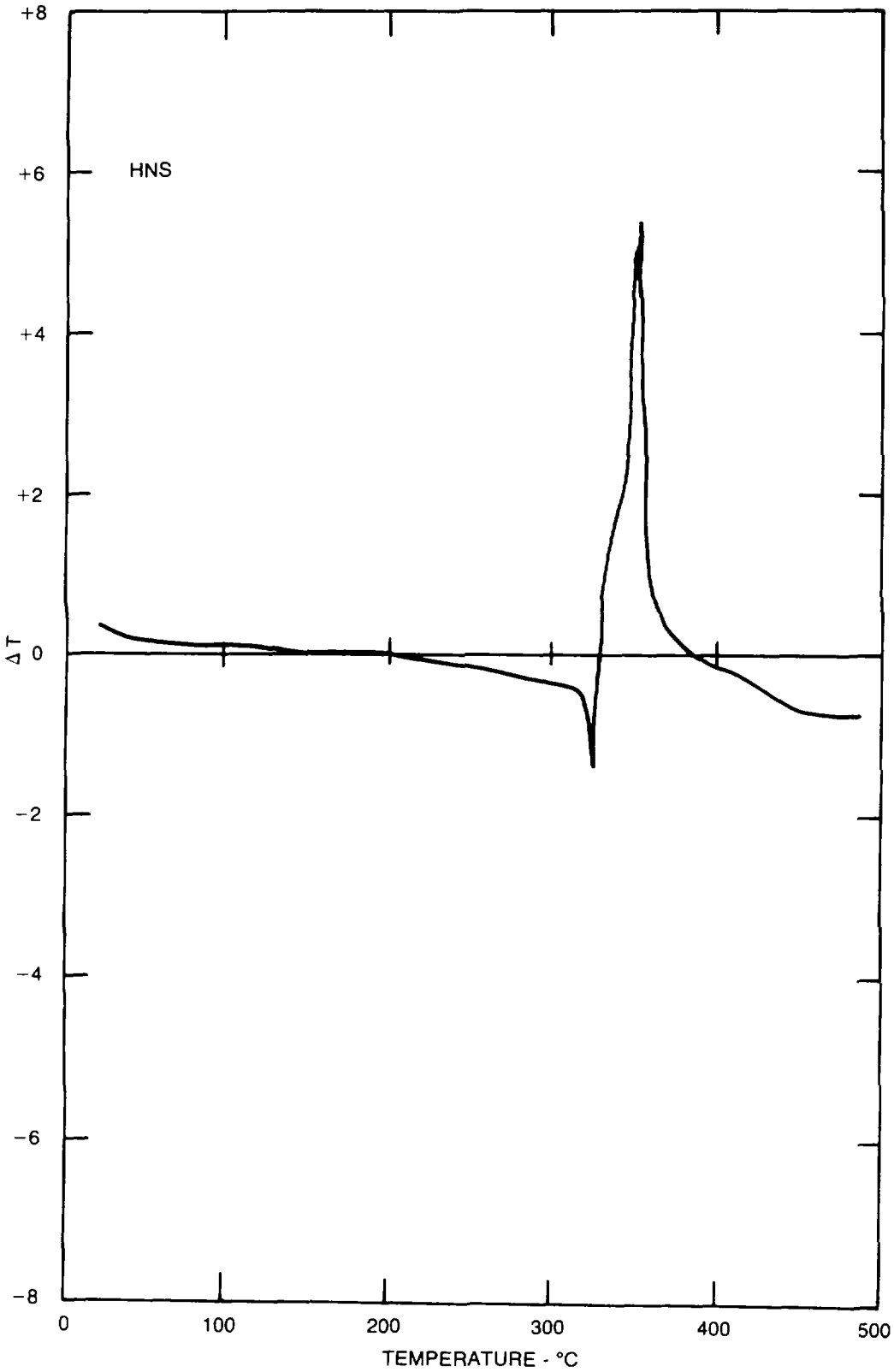


Figure 8-48. DTA curve for HNS.

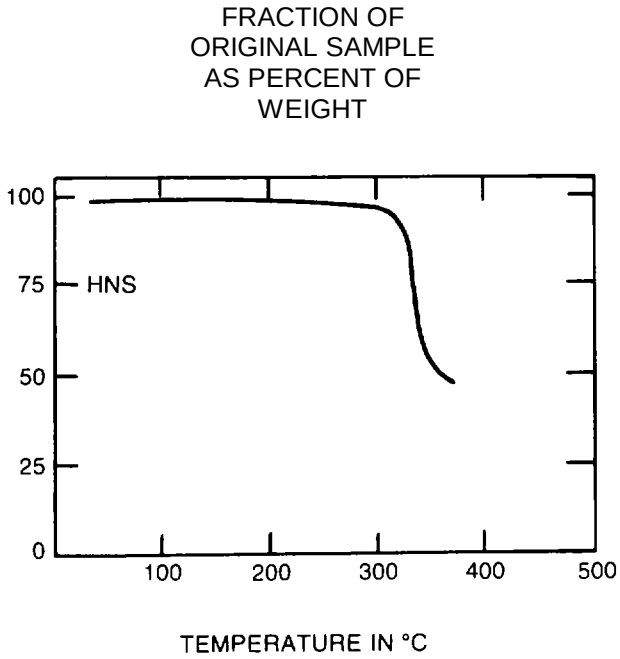


Figure 8-49. TGA curve for HNS.

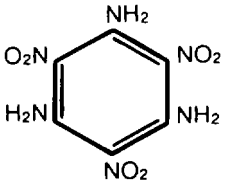


Figure 8-50. Structural formula for TATB.

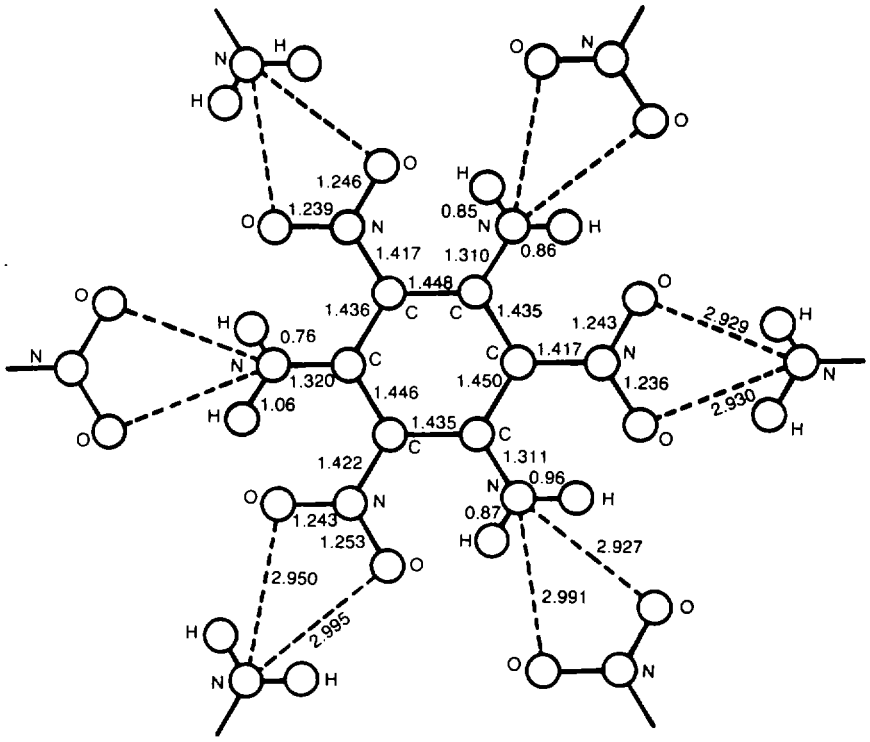


Figure 8-51. Configuration of the TATB molecule.

(2) The preferred method of preparation in the laboratory consists of the nitration of s-trichlorobenzene with a mixture of nitric acid and oleum at a temperature of 150°C for three hours. A toluene solution of the trinitrotrichlorobenzene (TCTNB) produced by the nitration is then aminated to yield TATB. The preferred manufacturing method to produce a particle size greater than 20 microns in 96 percent of the yield, suitable for PBXs and normal explosive compounds, is by the partially patented procedure that follows. The procedure is carried out in two steps; a nitration step and an amination.

(a) The equipment required is:

1 A 38 liter (10-gallon), glass-lined Pfaudler reactor capable of operation over a range of 200 to 150°C and pressure of 70 torr to 670 kilopascals (100 pounds per square inch), gauge, agitation provided by an anchor type blade at speeds of 20 to 200 revolutions per minute.

2 A glass-lined, concentric tube reflux condenser integral with the reactor.

3 A 189 liter (50-gallon), stainless steel reactor with agitator used in ice quenching of the nitration mixture.

4 Two 227 liter (60-gallon), stainless receivers used in filtrate storage and recovery.

5 A stainless steel, 28 centimeterx28 centimeterx5 centimeter plate and frame filter press, closed delivery washing type.

(b) The materials required for the nitration step are 2.5 kilograms of TCB with a melting point of 63°C to 64°C, 7.7 kilograms of $NaNO_3$ granular AR sodium nitrate, and 57.2 kilograms of 30 percent oleum. The oleum is charged to the glass-lined reactor, and the sodium nitrate is then added at a slow rate with full agitation. The reaction is quite exothermic, and jacket cooling is used to keep the temperature at 60° to 70°C. When the entire amount of sodium nitrate has been added and the exotherm peak has passed, the kettle contents are brought to a temperature of 100°C. The TCB is then charged to the reactor and steam is applied to the jacket to bring the temperature quickly to 145° to 155°C. The reactor contents are maintained at this temperature for a period of four hours. The small amounts of gas that are produced during the nitration are vented through the reflux condenser. At the end of the four hour reaction period, the contents are cooled to 40°C and discharged into the 50 gallon stainless steel reactor which contains approximately 113 kilograms of crushed ice. Full agitation is used during this quench step and the nitrous fumes are removed using a water sealed vacuum pump. The TCTNB product precipitates in the form of heavy, white crystals. With the stated quantity of ice, the temperature during dilution does not exceed 40°C, and hydrolysis of the product does not occur. The quenched reaction mixture is then pumped through the plate and frame press which discharges into a 60 gallon holding tank. Dynel cloth is used as the filtering medium. Only two frames are needed for the amount of cake produced. The cake is washed with several 20 gallon quantities of water, each followed with an air blow. This is continued until the wash water pH is 6 to 7. The cake is dried in open trays in a forced draft oven at 60°C for 16 hours. This completes the nitration step.

(c) The materials required for the amination step are 2724 grams of the TCTNB produced during the nitration step, 27.24 kilograms of technical grade toluene, 681 grams of water, 1044 grams of refrigeration grade anhydrous ammonia. The quantity of ammonia includes the amount for leakage and blow down. The TATB yield will be two kilograms. First, the TCTNB is dissolved in the toluene and the solution is clarified by filtration using Celite filter aid before transfer to the 10 gallon reactor. At this point 67 percent of the contaminating ammonium chloride by-product can be eliminated by adding 681 grams of water. The reactor system is then sealed and heating is continued until the contents are at 145°C. Since the amination step is moderately exothermic, the jacket steam is turned off at this time. Ammonia gas is then added to the reactor gas phase through an opening on the top of the kettle. The ammonia is metered through a rotameter at a rate of about 3632 grams per hour. When the ammonia overpressure reaches about 34.5 kilopascals (five pounds per square inch), the reactor system is purged of residual air by venting through the reflux condenser. The system is then resealed and the reaction is continued for approximately three hours. Moderate agitation is used during this period. During most of the three hour reaction period, conducted at 150°C, the pressure is maintained at 241.3 to 275.8 kilopascals (35 to 40 pounds per square inch, gauge). This represents an ammonia partial pressure of about 34.5 to 69 kilopascals (5 to 10 pounds per square inch). As the reaction progresses, a small amount of jacket heating may be necessary to maintain the 150°C temperature. The termination of the amination reaction is marked by a sharp rise in system pressure to about 413.7 kilopascals (60 pounds per square inch, gauge). After the pressure rise, the ammonia flow is shut off and the system is cooled to about 60°C. The system is then vented and approximately ten gallons of water is added to the reaction mixture with good agitation. The TATB product is recovered by filtration using the plate and frame press equipped with cotton cloths backed with filter paper. One frame is sufficient for the amount of product pro

duced. The cake is washed three times with 20 gallon portions of water, interspersed with air blows. This is sufficient to remove by-product NH4CI. To-dry the cake and remove volatile impurities, the cake is steamed for about ten minutes and air-blown before removal from the press. The cake is then dried in open trays in a forced draft oven at 100°C for 16 hours.

(d) The yield of this process is 89.0 percent of the theoretical with 4 percent of the particles below 20 microns in size. The crystal density of the product is 1.93 grams per cubic centimeter. If water was added during the amination process to remove the ammonium chloride contaminate the amount of chlorine impurities will be about 0.2 percent. If no water was added, the chlorine impurities will amount to about 0.6 percent. The process used for the manufacture of finely divided TATB suitable for use in booster pellets is slightly different. Using this process 82±.5 percent of the product will pass through a 20 micron sieve. In this process all the amination reactions are conducted in a 100 gallon stainless steel reactor heated with 517.125 kilopascals (75 pounds per square inch) steam to the jacket. The reactor is fitted with an ammonia inlet, a vent tube for azeotroping water from the system, and a thermowell. The TCTNB is first dissolved in toluene in a feed vessel and passed through a 1.5 micrometer in-line filter during transfer to the reactor. The solution is then heated to 140°C and the water azeotroped from the system. The ullage is then backfilled with ammonia and the temperature brought to 150°C. The reaction time varies between six and eight hours with completion indicated by a drop in ammonia flow as measured by the mass flow meter, an increase in system pressure approaching the 413.7 kilopascals (60 pounds per square inch, gauge) of the ammonia regulator and a decrease in the heat generated as indicated by the requirement of more steam to the reactor jacket. Product isolation involves cooling the reaction mixture to about 100°C, adding 40 liters of water, and vigorously stirring for half an hour. The warm mixture is isolated in a plate and frame press, washed with 85°C water for one hour, and steamed for one hour. The product is then dried for a minimum of 16 hours at a temperature of 115°C prior to sampling and packaging.

(3) TATB has an impact sensitivity of 11 inches by the Picatinny Arsenal apparatus for a seven milligram sample. By the ERL apparatus using a 2.5 kilogram weight with type 12 tools and without grit, the no detonation or reaction height is 200 centimeters. The point of 50 percent detonations is approximately 800 centimeters; the weight energy at this point is about 200 joules. The shock input to cause detonation has been determined to be 9500 joules per square meter. The five second explosion temperature test result is 520°C, and the auto ignition point is 320°C to 325°C. A charge of 0.30 grams of lead azide is required to initiate TATB. Table 8-43 lists the gap test results for TATB. Susan test results are shown in figure 8-52.

Table 8-43. Small Scale Gap Test Results for TATB

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.887	2.2	1.12
	1.519	21.3	4.12
LANL small scale gap test	1.872 (pressed)	3.4	0.13
LANL large scale gap test	1.786 (pressed)	2.8	41.68
	1.705 (pressed)	7.2	45.36
	0.81 (bulk)	56	49.3
PX gap test	1.883 (pressed)	-	approximately 5.3
	1.861 (pressed)	4.0	5.61
	1.700 (pressed)	12.3	14.10
	1.03 (bulk)	-	10.2 - 16.3

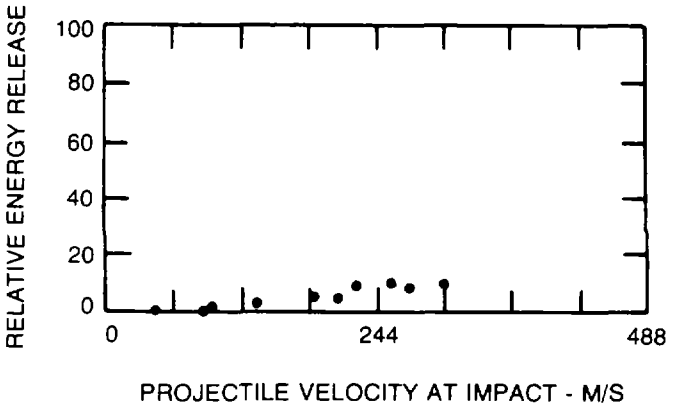


Figure 8-52. Susan test results for TATB.

(4) In the sand test, TATB crushes 42.9 grams of sand indicating a brisance of 90 percent of TNT. The detonation velocity as a function of density is given by the equation:

$$D = 2.480 + 2.85p$$

where D is in kilometers per second and p, the density, is in grams per cubic centimeter. This equation yields slightly higher results than reported by other investigators. The detonation pressure for a sample with a density of 1.847 grams per cubic centimeter is 259 kilobars. Table 8-44 lists, as a function of density, the Chapman-Jouguet pressure, energy, and isentropic exponent from watershock measurements.

Table 8-44. Detonation Characteristics of TATB

Density in grams per cubic centimeter	Detonation velocity in meters per second	UH20 in detonation meters per second	mH_20 meters per second	Pressure at explosive water interface in kilobars	Detonation pressure in kilobars	Isentropic exponent	Detonation energy in calories per gram
1.80	7,658	6,071	2,685	163.0	259.4	3.07	829
1.50	6,555	5,519	2,303	126.9	174.6	2.71	808

The Chapman-Jouguet pressure at crystal density is calculated to be 313 kilobars. Under oxygen deficient conditions the formation of detonation product gases proceeds according to the equation:

$$C_6H_6N_60_6 \rightarrow 3H_2O(g) + 3CO(g) + 3N_2(g) + 3C(s)$$

(5) TATB has excellent thermal stability. Differential Scanning Calorimeter measurements show exotherms at 330°C and 350°C when run at a heating rate of 10°C per minute. In the 1000 heat test, approximately .17 cubic centimeters of gas are evolved in 48 hours. In the 200°C test for 48 hours 0.5 cubic centimeters of gas are evolved; at 220°C for 48 hours 2.3 cubic centimeters are evolved. At 260°C for one hour approximately 1.2 cubic centimeters of gas are evolved. At 280°C 2.0 cubic centimeters of gas are evolved. Figure 8-53 shows the DTA curve for TATB.

f. 2,4,6-Trinitrotoluene (TNT).

(1) This explosive is also known as trotyl, tolit, triton, tritol, trilite, and 1-methyl-2,4,6-trinitrobenzene. TNT has been the most widely used military explosive from World War I to the present time. The advantages of TNT include low cost, safety in handling, fairly high explosive power, good chemical and thermal stability, favorable physical properties, compatibility with other explosives, a low melting point favorable for melt casting operations, and moderate toxicity. There are six possible ring nitrated TNT isomers. The alpha isomer, which is the one of military interest (figure 8-54) is symmetrical and will be referred to as TNT. The other five meta isomers will be identified by the Greek letters beta through eta excluding zeta. TNT is a yellow, crystalline compound with a nitrogen content of 18.5 percent, an oxygen balance to CO_2 of-73.9 percent, a molecular weight of 227.13, and a melting point of 80°C to 81°C. The freezing point, which is a more reproduceable quantity than the melting point, is used in the specification for the two military types of TNT that are procured. The freezing point is very sensitive to impurities. At atmospheric pressure, TNT boils at 345°C. Small amounts can be distilled rapidly at atmospheric pressure without an explosion, but explosions do occur with the longer heating periods required for larger quantities. TNT boils at 190°C, 210°C to 212°C, and 245°C to 250°C at 2 torr, 10 to 12 torr, and 50 torr, respectively. Unlike some other high explosives TNT does not undergo partial decomposition when melted. Samples of TNT have been melted and solidified at least 60 times with no significant decrease in the freezing point. The effect of moisture content on the freezing point is shown in table 8-45.

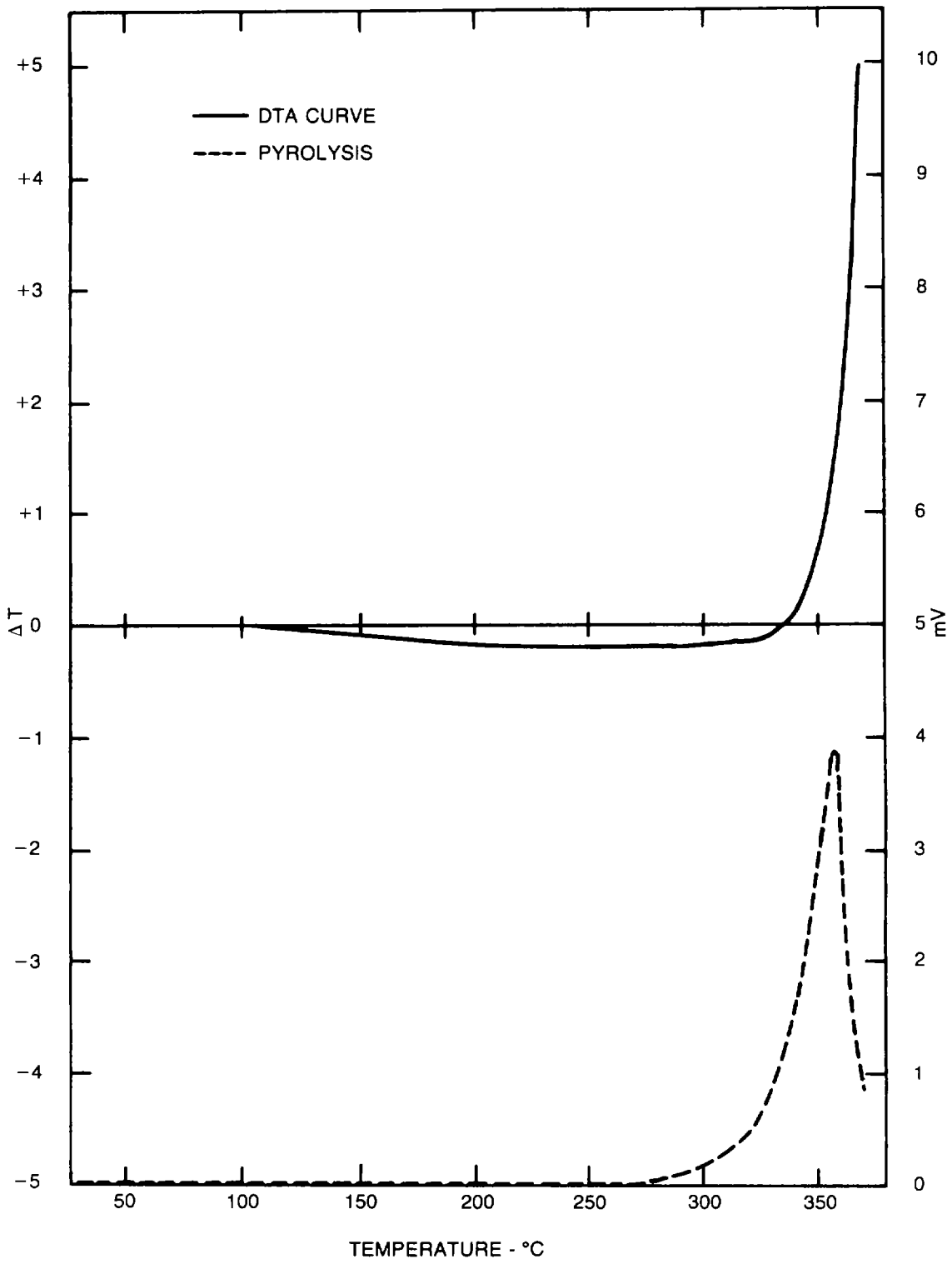


Figure 8-53. DTA curve for TATB.

Table 8-45. Effect of Moisture on the Freezing Point of TNT

Percentage of water	Freezing point in °C
0	80.59
0.1	80.35
0.2	80.20
0.3	79.99
0.5	79.78
1.0	79.09
2.5	77.93

Removal of moisture from a sample of TNT by heating at 1000C is slow as shown in table 8-46. The sample started with a water content of 0.3 percent.

Table 8-46. Removal of Moisture from TNT

Hours of heating at 100°C	Freezing point of sample in °C
0	79.99
2	80.30
3.5	80.46
5	80.55
6	80.59

At ordinary temperatures TNT is essentially nonvolatile. TNT has a crystal density of 1.654 grams per cubic centimeter, a cast density of 1.5 to 1.6 grams per cubic centimeter and a maximum pressed density of 1.63 to 1.64 grams per cubic centimeter. Table 8-47 shows the density of TNT as a function of loading pressure although densities as high as 1.64 grams per cubic centimeter have been reported.

Table 8-47. Density as a Function of Loading Pressure for TNT

Pressure in kilopascals	Pressure in pounds per square inch	Density in grams per cubic centimeter
20,685	3,000	1.34
34,475	5,000	1.40
68,950	10,000	1.47
82,740	12,000	1.49
103,425	15,000	1.52
137,900	20,000	1.55

The density of the liquid in the temperature range of 83°C to 120°C is given as a function of temperature by the equation:

$$D=1.5446-1.016x10^{-3}t$$

where D, the density, is in grams per cubic centimeter and t is in degrees centigrade. Several crystalline structures of TNT are known. Samples of TNT obtained by sublimation onto a condensing surface held at a temperature, 780C, very close to the melting point consist solely of the simple monoclinic form. Freezing the melts at a temperature very close to the melting point also yields a monoclinic form. Crystallization from solvents at room temperature or from strongly supercooled melts yield primarily monoclinic variant forms. Orthorhombic TNT is formed by crystallization from solvents at low temperatures. The unit cell dimensions of the monoclinic form are a=21.275 Angstroms, b=6.093 Angstroms, and c=15.025 Angstroms with eight molecules per unit cell. The unit cell dimensions of the orthorhomic form are a=15.007 Angstroms, b=20.029 Angstroms, and c=6.098 Angstroms. At least seven morphological types of TNT have been identified. Unusual crystal growth has been Observed when TNT crystals are held near the melting point. Additives have a great effect on the crystallization process. Picryl chloride induces the formation of the orthorhombic form. Other picryl derivatives, especially 2,4,6-trinitrostilbene, drastically reduce the linear crystallization rate. Two compounds, hexanitrobibenzyl (HNBB) and methylpentanitrodiphenylmethane (MPDM), which are introduced during the purification phase of manufacture, have the same effect. These compounds have adverse effects on melt loading operations. During the melt loading operation cracks and voids tend to form in the cast material. The cracks are caused by an 11 percent shrinkage in the volume of the TNT upon solidification. The voids appear between the grains of the large orthorhombic crystals which are formed. A method to preclude the cracks and voids involves a procedure for overcoming the strong tendency of molten TNT to supercool with subsequent slow initial crystallization at the melt surface resulting from an insufficiency of crystal nuclei. Addition of solid seed TNT crystals to the melt while stirring yields a smooth casting with the desired very fine, randomly-oriented, monoclinic crystals. TNT prepared in this fashion undergoes irreversible crystal growth upon thermal cycling if the maximum temperature is above about 30°C to 35°C. For temperatures above 35°C a linear relationship exists between the growth with a corresponding decrease in density and the maximum temperature attained in the cycle. The growth correlates with the quantity of impurities present. However, the high viscosity of the mixture and the fine temperature control required, make this procedure impractical. Another procedure involves the addition of less than 2 percent HNS. The crystals formed are largely monoclinic and the casts are of sufficient quality. This method is a promising procedure, however TNT

surveillance test samples containing 0.5 percent HNS submitted to thermal cycling showed increased exudation, irreversible crystal growth, decreasing density, and, eventually, complete crumbling.

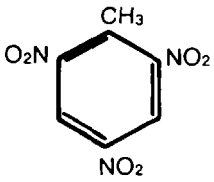


Figure 8-54. Structural formula for TNT.

(2) The viscosity of liquid TNT is 0.139 and 0.095 poise at 85°C and 100°C, respectively. The refractive index values are alpha = 1.543, beta =1.674, and gamma=1.717. These values indicate a hardness of 1.4 on the Mohs scale. The observed molecular refraction is 49.6. The surface tension of liquid TNT as a function of temperature is shown in table 8-48.

Table 8-48. Surface Tension of Liquid TNT

Temperature in °C	Surface tension in dynes per centimeter
80	47.07
85	46.63
87.6	46.36
90	46.04
95	45.62

Cast TNT with a density of 1.62 grams per cubic centimeter has a compressive strength of 9,515 to 9,653 kilopascals (1,380 to 1,400 pounds per square inch). The dielectric constant, measured at 35 giga hertz, is shown in table 8-49 for crystal and flaked TNT.

Table 8-49. Dielectric Constant of TNT

Density in grams per cubic centimeter	Dielectric constant, crystals	Dielectric constant, ground flakes
0.9	2.048	2.092
1.2	2.347	2.362
1.5	2.795	2.773
1.7	3.178	3.125

The solubility of TNT in various solvents is shown in table 8-50. Over the range of 82°C to 95°C, molten TNT absorbs 3.22 milliliters of air per 100 grams of TNT. The approximate specific heat of TNT in calories per gram per degree centigrade is given by the equations:

$0.254+(7.5x10\text{-}4)\ T \qquad T < 80.5°C$
$0.329+(5.5\ x10\text{-}4)\ T \qquad T > 80.5°C$

Additional information concerning the specific heat, entropy, and enthalpy of TNT is available in table 8-51. Please note the difference in units from the above data.

Table 8-50. Solubility of TNT

	Solubility in grams per 100 grams of solvent at °C							
	0	20	25	30	40	50	60	75
Ethanol (95%)	0.65	1.23	1.48	1.80	-	4.61	-	19.5
Ether	1.73	3.29	3.80	4.56	-	-	-	-
Acetone	57	109	132	156	-	346	-	-
Carbon tetrachloride	0.20	0.65	0.82	1.01	-	3.23	-	24.35
Chloroform	6	19	25	32.5	-	150	-	-
Ethylene chloride	-	18.7	22	29	-	97	-	-
Benzene	13	67	88	113	-	284	-	-
Toluene	28	55	67	84	-	208	-	-
Carbon disulfide	0.14	0.48	0.63	0.85	-	-	-	-
Methyl acetate	-	72.1	80	99	-	260	-	-
Triacetin	-	-	37.7	-	-	-	-	-
Butyl carbitol acetate	-	24	-	-	-	-	-	-
Sulfuric acid	-	4	-	-	-	-	-	-
N,N-dimethylformaide	90	119 at 150C	142	-	-	-	-	-
Dimethyl sulfoxide	-	-	128	-	-	-	-	-
1-Methyl-2-pyrrolidinone	-	-	118	-	-	-	-	-
Pyridine	-	137	-	-	-	-	-	-

Table 8-50. Solubility of TNT (Cont)

	Solubility in grams per 100 grams of solvent at °C							
	0	20	25	30	40	50	60	75
Chlorobenzene	-	33.9	-	-	-	-	-	-
1,2 Dichloroethane	-	18.7	-	-	-	-	-	-
Diethyl ether	-	3.29	-	-	-	-	-	-
Trichloroethylene	-	3.04	-	-	-	-	-	-
Methanol	-	-	-	-	9.5	-	31.6	-

Table 8-51. Specific Heat, Enthalpy, and Entropy of TNT

Temperature in °K	Specific heat in joules per mole per °K	Enthalpy in joules per mole	Entrophy in joules per mole per °K
10	3.116	10.390	1.732
30	32.71	352.77	17.49
50	60.41	1293.0	40.90
70	82.52	2731.0	64.89
90	101.70	4576.7	87.98
110	118.76	6784.8	110.08
130	133.54	9309.6	131.13
150	148.30	12128	151.28
170	162.84	15240	170.73
190	177.15	18640	189.63
210	191.24	22325	208.05
230	205.09	26288	226.07
250	218.72	30527	243.74
270	232.12	35036	261.08
300	251.80	42296	286.56

Values for the heat of combustion for the crystal range from 809.18 to 817.2 kilocalories per mole. The heat of formation for the liquid or crystal is between 10 and 19.99 kilocalories per mole. The free energy of formation for the crystal is 50.92±0.83. The heat of fusion computed by interpolation of enthalpy curve is 23.53 calories per gram although values from 20.2 to 25.2 have been reported. Values for the heat of sublimation range from 23.2 to 33.7 kilocalories per mole. The Gibbs free energy of sublimation is 69.6☆3.0 kilojoules per mole and the standard entropy of sublimation is 146.2±1.3 joules per mole per degree Kelvin. The heat of vaporization is reported in the range of 17 to 22.7 kilocalories per mole. The maximum calculated heat of detonation with liquid water is 1.41 kilocalories per gram; with gaseous water the value is 1.29 kilocalories per gram. For a charge with a density of 1.54 grams per cubic centimeter, the measured values are 1.09 kilocalories per gram with liquid water and 1.02 kilocalories per gram with gaseous water. The enthalpy of TNT relative to the enthalpy at 0°C for the range 25°C to 68°C is expressed by the equation:

$$H - H_0 = 0.045 + 0.24625\ T + (4.205 \times 10\ -4)\ T2$$

where T, the temperature, is in units of degrees centigrade. For the range 83°C to 117°C the relative enthalpy is expressed by the following equation:

$$H - H_0 = 12.450 + 0.45023\ T - (4.0091 \times 10^{-4})\ T^2$$

In this equation T is also in units of degrees centigrade. The standard enthalpy is 113.2 ±1.5 kilojoules per mole. The standard entropy for the crystal is 68.12±0.38 calories per degree Kelvin per mole. Thermal diffusivity as a function of temperature is shown in table 8-52.

Table 8-52. Thermal Diffusivity of TNT

Thermal diffusivity in centimeters squared per second x 10^4 at 25°C	Density in grams per cubic centimeter
19.7	0.64
15.0	0.783
12.1	0.980

TNT forms binary and ternary eutectics with various types of nitro compounds and nitrate esters. The dinitrotoluenes and the unsymmetrical TNT isomers form

eutectics with 2,4,6-TNT which melt just above room temperature. Removal of these impurities is necessary to prevent exudation from TNT based explosives. TNT is used as a shell filler and as an ingredient in many composition explosives. Dinitrotoluene is also used in the filling of shells.

(3) The following sections of this subparagraph deal with the chemical reactivity of TNT. The sections are divided first by the structure of the TNT molecule involved in the reaction, such as the methyl group, the nitro group, and the aromatic ring. Then the reactions are further subdivided by the type of reaction.

(a) Reactions of the methyl group.

1 The methyl group can be halogenated. Monochlorination can be affected with sodium hypochlorite according to the following equation.

$$PiCH_3 \xrightarrow{NaOCl} PiCH_2Cl$$

(Pi =2,4,6-trinitrophenyl)

The chloride, prepared in situ, is important as the intermediate for preparing 2,2',4,4',6,6'-hexanitrostilbene according to the reaction:

$$2PiCH_2Cl \xrightarrow{Base} PiCH{=}CHPi + 2HCl$$

(HNS)

HNS is a thermally-stable explosive and a nucleant for improving the crystallization habit of TNT in explosive formulations such as composition B. In the presence of excess TNT, the chloride yields 2,2',4,4',6,6'-hexanitrobibenzyl (HNBB) which can be oxidized to HNS according to the equation:

$$PiCH_2Cl + PiCH_3 \xrightarrow{Base} PiCH_2Cl + PiCH_3 \xrightarrow{Oxidation} HNS$$

(HNBB)

Destructive chlorination to chlorpicrin (Cl3CNO2) has been noted on warming TNT with Ca hypochlorite. Small amounts of chloropicrin are formed during the preparation of HNS from TNT and sodium hypochlorite. On a production scale, an environmental problem is created since this compound is a toxic lachrymator. Heating TNT under pressure at 150°C to 160°C with phosphorus pentachloride and a trace of iodine is said to give a mixture of products including mainly 2,4,6-trinitrobenzotrichloride and pentarhlorobenzyl chloride. Others, however, were unable to prepare the former compound in this way. TNT can be monobrominated with sodium hypobromite, or less conveniently by heating under pressure at 1600C with bromine and magnesium carbonate. Heating TNT with bromine and a trace of iodine under pressure at 200°C gives pentabromobenzyl bromide according to the equation:

$$PiCH_3 \xrightarrow[\text{Trace } I_2]{Br_2} C_6Br_5CH_2Br$$

2 The methyl group can be oxidized. The oxidation can proceed stepwise through the alcohol and aldehyde to the acid, as follows:

$$PiCH_3 \xrightarrow{O} PiCH_2OH \xrightarrow{O} PiCHO \xrightarrow{O} PiCOOH$$

Trinitrobenzoic acid can be prepared by this procedure. The alcohol and aldehyde are more easily oxidized than the TNT so the oxidization cannot be stopped at either of these stages. Other reactions must be used to prepare these products. Trinitrobenzoic acid is easily and quantitatively converted to 1,3,5-trinitrobenzene (TNB), an explosive superior to TNT in many ways, but more expensive to make. Oxidation of TNT is the preferred procedure for preparing TNB. This can be done in 85 percent yield by heating TNT with 90 percent nitric acid at 1500C under pressure for 18 hours, but the preferred laboratory procedure involves oxidation with potassium or sodium dichromate in concentrated sulfuric acid. Yields in this procedure vary from 43 to 46 percent to 86 to 90 percent, apparently depending on minor variations in technique. The addition of acetic acid as cosolvent is said to give a 98 percent yield of the acid. Oxidation of the methyl group occurs during TNT manufacture with 2 to 4 percent of yield loss occurring in this way. Under certain conditions the alcohol, as a nitrate, and the aidehyde are formed by the oxidation. The two compounds then react to form 2,2'-dicarboxy-3,3',5,5'tetranitroazoxybenzene as shown in figure 8-55. This compound, called white compound, coats the equipment piping and must be cleaned off. By a suitable variation in conditions, this reaction can be minimized, with the alcohol and aldehyde being oxidized preferentially to the acid. Crude TNT contains small amounts of all four of these compounds. About 10 percent of each trinitrobenzyl alcohol and trinitrobenzaldehyde are formed by side reactions during the preparation of HNS from TNT using sodium hypochloride. The two compounds also appear in small amounts during the action of heat or light on TNT. TNT can be oxidized to HNBB, in poor yield, by simply adding base to a solution of TNT in a suitable solvent according to the reaction:

$$2PiCH_3 \xrightarrow{O} PiCH_2CH_2Pi + H_{2O}$$

(HNBB)

The nitro groups in a portion of the TNT are the oxidizing agent. Small amounts of HNBB are formed by this reaction during the purification of TNT with alkaline sodium sulfite. Air oxidation in the presence of base and copper sulfate is claimed to give yields as high as 82 percent.

$PiCH_2ONO_2 + PiCHO$

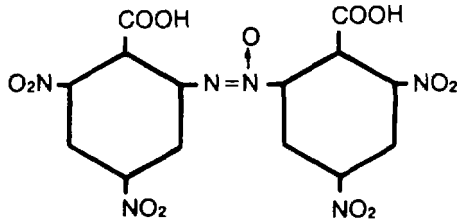


Figure 8-55. White compound.

3 The methyl group can react with aldehydes. Formaldehyde reacts with TNT as follows:

$$PiCH_3 + CH_2O \longrightarrow PiCH_2CH_2OH$$

The reaction can be carried out by heating TNT in a basic solution of aqueous formaldehyde. TNT is only poorly soluble in this solution, however. Better results are obtained when acetone is used as a cosolvent. TNT undergoes the Mannich reaction with formaldehyde and various secondary amines according to the equation:

$$PiCH_3CH_2O + R_2NH \longrightarrow PiCH_2CH_2NR_2$$

In this reaction dioxane was used as solvent and 2 percent sodium hydroxide was added as catalyst; piperazine forms a 1:2 derivative. Benzaldehyde reacts with TNT to form two compounds. The molar ratio between the reactants in one of the compounds is one to one. The reaction proceeds according to the equation:

$$PiCH_3 + C_6H_5CHO \longrightarrow PiCH = CHC_6H_5$$

The reaction is catalyzed by piperidine and is run in an aromatic solvent such as benzene or toluene. A series of monosubstituted benzaldehydes react similarly as do also terephthalaldehyde and isophthalaldehyde. One mole of both of the last two reactants combines with two moles of TNT. In the second compound benzaldehyde forms with TNT, one mole of benzaldehyde reacts with two moles of TNT. The reaction proceeds according to the equation:

$$2PiCH_3 + C_6H_5CHO \longrightarrow (PiCH_2)_2CHC_6H_5$$

This reaction is also catalyzed by piperidine but is run in pyridine. Only traces of HNS were obtained from TNT and 2,4,6-trinitrobenzaldehyde.

4 The methyl group reacts with halides and unsymmetrical TNT isomers. In the presence of equivalent potassium hydroxide, TNT reacts as follows with various halides such as 4-nitrobenzyl bromide, picryl chloride, or 2,4-dinitrofluorobenzene:

$$PiCH_3 + RX \xrightarrow{KOH} PiCH_2R + KX$$

Only compounds with highly reactive halogens yield products by this reaction. As the halide reactivity decreases, increasing amounts of HNBB are formed from TNT in the presence of a base. This type of reaction can also occur with compounds containing reactive nitro groups. In the manufacture of TNT, 2,4,6- and 2,4,5- TNT interact in this manner to form MPDM, as shown in figure 8-56. A similar compound can be made from 2,4,6-TNT and 2,3,4-TNT.

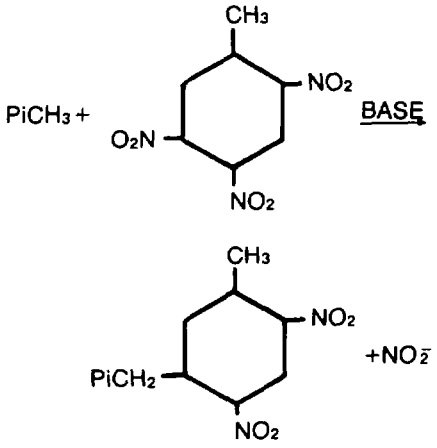


Figure 8-56. TNT and 2,4,5-TNT reaction.

5 The methyl group reacts with various nitroso compounds. The reaction with 4-nitrosodimethylaniline, reaction (A), and subsequent hydrolysis, reaction (B), to yield 2,4,6- trinitrobenzaldehyde, PiCHO, is shown below:

$$PiCH_3 + ONC_6H_4N(CH_3)_2 \xrightarrow{(A)}$$

$$PiCH = NC_6H_4N(CH_3)_2 \xrightarrow{(B)}$$

$$PiCHO + H_2NC_6H_4N(CH_3)_2$$

This is the favored procedure for preparing 2,4,6-trinitrobenzaldehyde. Reaction (A) is run at room temperature in pyridine, using iodine as a catalyst, or in a alcohol-acetone mixture with anhydrous sodium carbonate as a catalyst. Reaction (B) proceeds in a strong aqueous hydrochloric acid solution; overall yields are 39 to 52 percent. Reaction (A) can be run in an aqueous medium in the presence of light with a yield of 80 percent and less by-product formation than in the other methods. Other types of aromatic nitroso compounds, for example nitrosobenzene and nitrosotoluene, form nitrones according to the equation:

$$PiCH_3 + 2RNO \longrightarrow PiCH{=}NR{+}X \quad (X = O)$$

where X depends on the specific reaction.

6 The methyl group can undergo nitration and nitrosodation. The reaction with alkaline fluorotrinitromethane proceeds according to the equation:

$$PiCH_3 + FC(NO_2)_3 \xrightarrow{Alk} PiCH_2NO_2$$

Several products are formed with nitrosylchloride, as shown in figure 8-57.

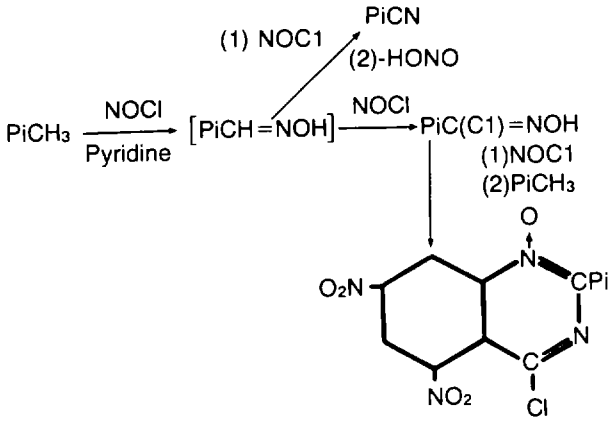


Figure 8-57. Reaction of TNT with nitrosylchloride.

7 Other miscellaneous reactions of the methyl group include the reaction with N,N-dimethylformamide and phosphorus oxychloride in which TNT undergoes the Vilsmeier reaction as shown below:

$$PiCH3 \xrightarrow[(2)\ KOH]{(1)\ DMF\text{-}POCl_3} PiCH(CHO)_2$$

The resulting dialdehyde was converted to derivatives. The reaction between phthalic anhydride and TNT is reported to form a phthalide derivative as shown in figure 8-58. However the reaction could not be duplicated. When TNT couples with diazonium compounds, the most likely reaction is:

$$PiCH_3 + RN_2Cl \longrightarrow PiCH_2N{=}NR$$

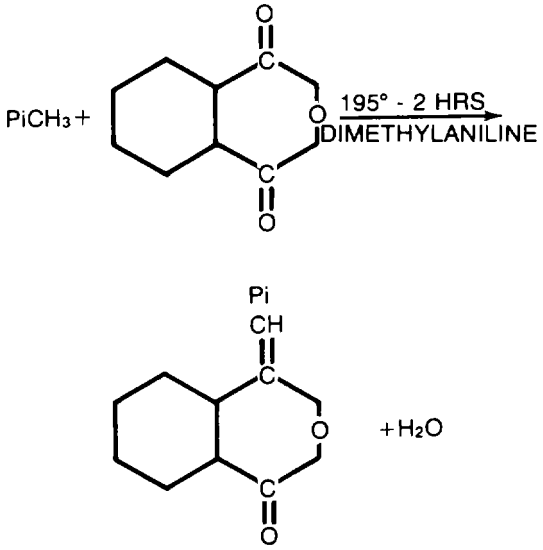


Figure 8-58. Reaction between TNT and phthalic anhydride.

(b) Reactions of the aromatic ring.

1 TNT can be monomethylated to trinitro-m-xylene in 9 to 32 percent yield by heating with lead tetracetate or acetyl peroxide, or by electrolysis with acetic acid-sodium acetate. Attempts to introduce more methyl groups have been unsuccessful.

2 Reduction of TNT with sodium borohydride gives 1-methyl-2,4,6-trinitrocyclohexane in 21 percent yield according to the reaction shown in figure 8-59.

3 One mole of TNT reacts with three moles of diazomethane. The compound obtained from diazomethane and 1,3,5-trinitrobenzene has the seven member ring shown in figure 8-60.

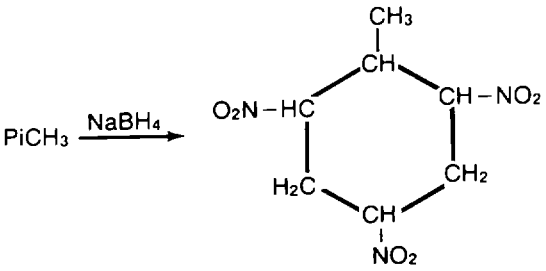


Figure 8-59. Reduction of TNT with sodium borohydride.

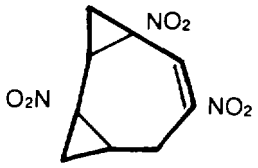


Figure 8-60. Seven member ring structure.

4 TNT undergoes methyl group halogenation as well as ring halogenation with loss of the nitro groups at 150°C to 200°C.

5 Ring cleavage to chloropicrin occurs with alkaline hypochlorites. TNT can also be destroyed by treatment with ozone, in the presence of base, or ultraviolet light. In both cases, the 2,4,6-trinitrobenzyl anion in generated, which is presumably the reactive species.

(c) Reactions of the nitro groups.

1 TNT can be reduced to the triamino compound with tin and hydrochloric acid, or with hydrogen using a Pd-$BaSO_4$ catalyst as shown in figure 8-61.

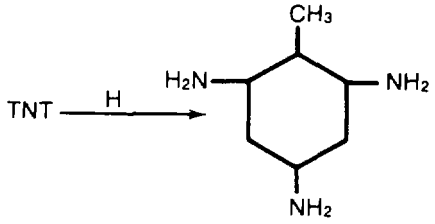


Figure 8-61. Reaction of TNT with hydrogen.

2 4-Amini-2,6-dinitrotoluene can be made by treating TNT in dioxane with ammonium sulfide. A 37 percent yield of material of 99 percent purity was so obtained.

3 Reduction of TNT with ethanolic ammonium sulfide yields 2,4-diamio-6-nitrotoluene. Reaction of TNT with ethyl alcoholic hydrogen sulfide containing a small quantity of ammonia gives a mixture comprising 22 percent unreacted TNT, 22 percent 4-amino-2,6- dinitrotoluene, 4 percent 2-amino-4,6-dinitrotoluene, 44 percent 4-hydroxylamino-2,6-dinitrotoluene, and 8 per- cent 2-hydroxylamino-4,6-dinitrotoluene. The 4-hydroxylamino compound can be extracted from the reaction mixture. The 4-amino-2,6-dinitrotoluene is an intermediate for one procedure for preparing the thermally-stable, insensitive explosive TATB. The reaction is shown in figure 8-62. Reaction (A) involves an unusual demethylation as well as nitration. The above partial reduction products of TNT, among others, are formed during biodegradation and during the destruction of TNT by reaction with sodium or ammonium sulfide. TNT does not undergo hydrolysis during storage of a saturated solution in sea water over a period of several months at 25°C in active glassware.

(d) Some reactions involve both the nitro and methyl group. An important aspect of TNT reactivity involves redox reactions between the reactive methyl group and the nitro groups, a type of reaction which can be initiated by various energetic stimuli including thermal and photochemical as well as chemical. The following discussion indicates the reactions are both intra- and intermolecular, ultimately leading to diverse monomeric and polymeric products. The intramolecular type involves reaction between the methyl group and an ortho nitro group. This reaction occurs especially easily and is often the first step for other reactions. The reaction also applies to many other derivatives and analogues of 2-nitrotoluene.

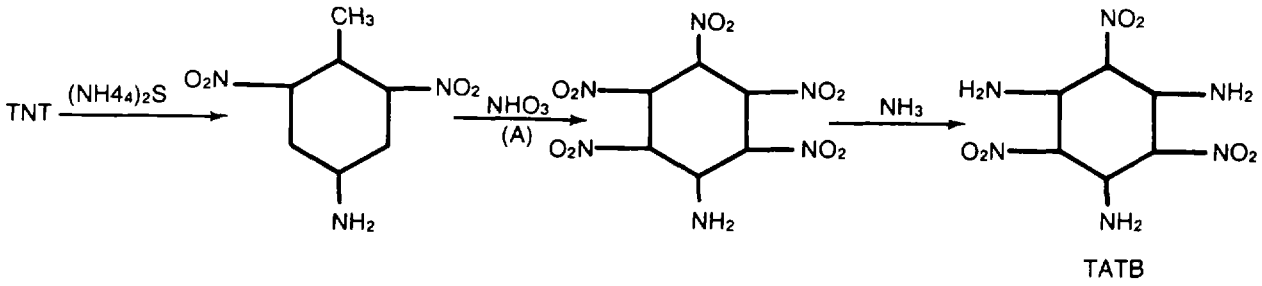


Figure 8-62. Production of TATB from TNT.

1 All types of nitro compounds react easily with bases forming diverse types of products. In the case of TNT, 2,4,6-trinitrobenzyl anion (I) is formed initially and rapidly as shown in figure 8-63. The ion is a highly reactive species thought to be intermediate in the many reactions of TNT conducted under basic conditions. The anion is formed without side reactions by the action of 1,1',3,3'-tetramethylguanidine in dimethylformamide solvent. Based on spectrophotometric evidence, the first dissociation constant of TNT with NaOH is $1.02 \pm 0.2 \times 10^{-12}$. Highly-colored Jackson-Meisenheimer, or sigma, complexes of structure (II) or (III), also shown in figure 8-63, are formed by addition to the ring system. These compounds are formed in both aqueous and anhydrous mediums and with a variety of organic and inorganic nucleophiles. Sulfite ion forms a complex of structure (III) which is a source of yield loss during the purification of TNT if the pH exceeds eight. Cyanide ion also forms a complex of structure (III). TNT as the anion (I) can react with other TNT anion (I)'s and produce adducts of structure (II). A similar reaction takes place with 1,3,5-trinitrobenzene. Primary and secondary aliphatic amines also form sigma complexes. Upon solution in liquid ammonia, a complex of type (III) is initially formed with no evidence of type (I) having been formed. With time, a second NH_2 group becomes attached to the ring carbon with the methyl group; this compound has cis- and trans-isomers. Removal of the ammonia gives a red residue comprising about 50 percent TNT. Acetone carbanion forms a complex of structure (III). Methoxide, ethoxide, and isopropoxide form complexes of structure (II). T-butoxide ion yields structure (I) with TNT.

2 In some cases each mole of TNT can add up to three moles of a base. The compounds formed with potassium hydroxide in a dilute aqueous solution are shown in figure 8-64. The one to one molar ratio compound is the same type compound as structure (II) shown in figure 8-64. Three moles of potassium ethoxide can also react. Addition of two moles of sodium sulfite is also possible.

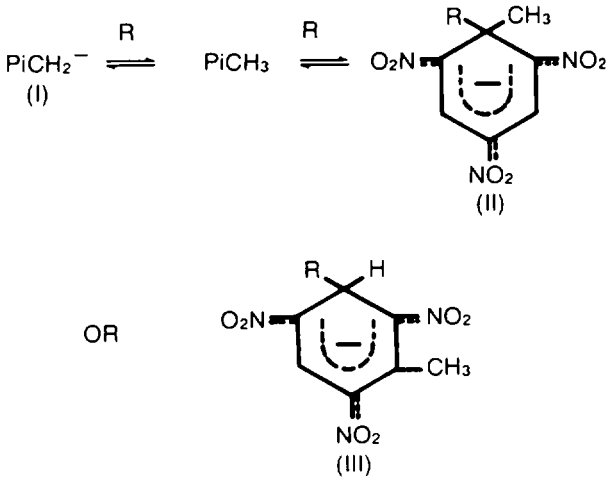


Figure 8-63. Reaction of TNT with bases.

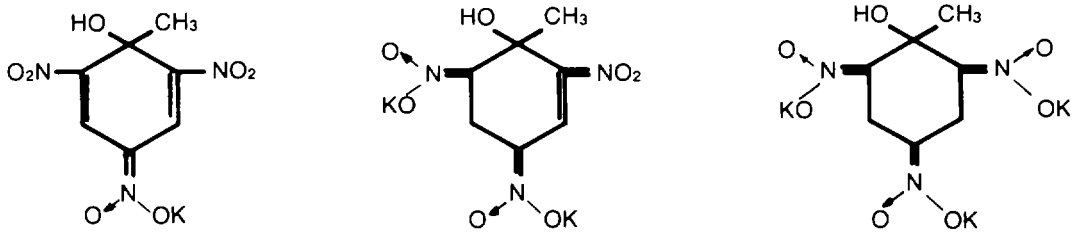


Figure 8-64. Reaction of TNT with potassium hydroxide.

3 Side reactions can occur, especially in the presence of excess base at elevated temperatures and prolonged times of reaction. Potassium hydroxide and anhydrous ammonia can form nitrite ions by clevage of nitro groups. 2,4,5-Trinitrophenol and 3,5- dinitrophenol have been isolated from the reaction of TNT with NaOH. Redox reactions give polymeric materials via the formation of azo and azoxy groups, as shown in figure 8-65 for the case of phenylhydrazine. Dimerization also occurs by the redox coupling of two molecules of TNT to form $PiCH_2CH_2Pi$. The oxidant in this case is TNT. The complexes of long-chain, primary-secondary aliphatic amines with TNT have low water solubility and may be useful for the removal of TNT from aqueous solutions. The rapid reactions with isopropylamine in acetone has been studied as a possible procedure for the neutralization of TNT in land mines.

(e) The degradation of TNT by electron impact has been studied. The initial step is a methyl-hydrogen transfer to an adjacent nitro-oxygen which is followed by cleavage of the hydroxyl group. The resulting ion then degrades further by several routes which include the loss of small stable molecules such as CO, NO, HC = CH, HCN, etc. All of the TNT isomers undergo similar methyl-hydrogen transfer as the first step except for the 3,4,5-isomer, which lacks the adjacent methyl and nitro groups.

(f) In the manufacturing process, absorption by activated carbon filters is commonly employed to control pollution. The TNT is absorbed at many of the numerous high-energy sites on the surface of the carbon. Basic materials, introduced during activation of the carbon by combustion and oxidation are also present at these sites, then induce oxidation-reduction reactions of the methyl with the nitro groups in the TNT. This is manifested in the simplest form by the formation of small amounts of trinitrobenzoic acid and trinitrobenzene. Coupling and polymerization also occur, via generation of azo and azoxy linkages among others, yielding complex, high molecular-weight materials which are irreversibly bound to the surface and clog the pores of the carbon. This process is, therefore, generally similar to that involved in the thermal and basic decomposition of TNT. When TNT and activated carbon are dry-mixed at room temperature, the TNT rapidly and completely displaces the air absorbed on the carbon. The carbon has a strong catalytic effect on the thermal decomposition of TNT. At 120°C, a 90/10 TNT/carbon mixture decomposes 12.3 times as fast as pure TNT, and a 50/50 mixture 113 times as fast.

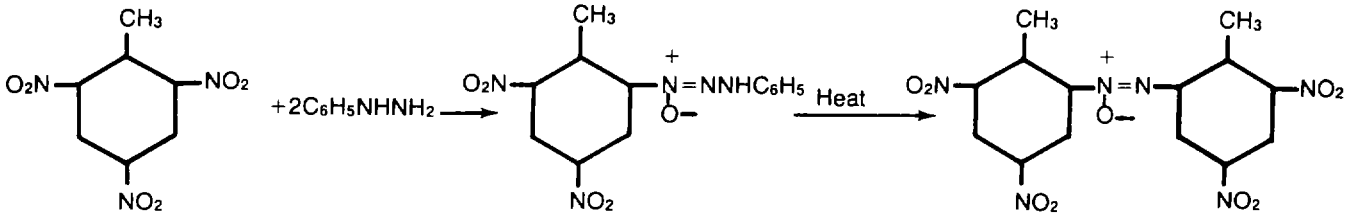


Figure 8-65. Reaction of TNT with phenylhydrazine.

(4) Of the six possible TNT isomers, five are unsymmetrical or meta isomers. Physical properties of the six are summarized in table 8-53.

Table 8-53. Isomers of TNT

Isomer	Melting point in °C	Position of reactive nitro group	Deflagration temperature in °C	
			Pure	With Na2CO3
2,4,6 (alpha)	80.9	This is the symmetrical isomer so has none	281-300	
2,3,4 (beta)	110-111	3	301-303	208-215
2,4,5 (gamma)	104-104.5	5	288-293 290-310	191-198
3,4,5 (delta)	133-134	4	305-318	252
2,3,5 (epsilon)	96-97	2	333-337	268-271
2,3,6 (eta)	111.5-112.5	3	327-335	249-250

The unsymmetrical isomers all differ from the 2,4,6isomer in having notably higher melting points and in having one nitro group which is easily replaced by treatment with various nucleophilic reagents; the position of this group is indicated in table 8-53. Consequently, the reactions of 2,4,6-TNT under basic conditions are entirely different from those of the other five isomers. All of the unsymmetrical isomers have been found in crude TNT, ranging from about 2.5 percent for the 2,4,5-isomer and 1.5 percent for the 2,3,4-isomer down to 0.006 percent for the 3,4,5-isomer. The meta isomers form low melting point eutectics with TNT and so must be removed during the manufacturing process.

(5) TNT is manufactured by the nitration of toluene in successive steps. In the first step toluene is nitrated to mononitrotoluene (MNT). The MNT is then nitrated to dinitrotoluene (DNT). The last step is the nitration of DNT to TNT. The three steps are carried out under different conditions. The trinitration is carried out at a higher temperature than the dinitration, which is carried out at a higher temperature than the mononitration. The trinitration also requires a stronger mixed acid than the dinitration, which requires a stronger mixed acid than the mononitration. In the continuous production system installed at Radford Army Ammunition Plant these requirements are met with a counter flow process. The system consists of eight nitrators. Toluene is introduced into nitrator number one and moves successively through each nitrator to nitrator number eight where nitration to TNT is completed. Mixed acid is introduced into nitrator number eight and moves successively through each nitrator to nitrator number one. The mixed acid consists of nitric acid, 40 percent oleum, and water. Fortification with nitric acid is required between nitrators. The temperature of nitrator number one is maintained at 50°C to 55°C. Each successive nitrator is maintained at a higher temperature than the one immediately proceeding. Nitrator number eight is maintained at about 100°C. Each nitrator is equipped with an agitator. The solubility of toluene and the nitrotoluenes in mixed acid is very low. Therefore, the nitration proceeds in a two phase system and the rate of nitration depends on dispersion. The dispersion depends on keeping the two phases well stirred. Figure 8-66 shows the yield of mononitrotoluene as a function of the rate of stirring with a mixed acid consisting of 11 percent nitric acid, 64 percent sulfuric acid, and 25 percent water for a nitration time of 30 minutes. The results with the use of 40 percent oleum, which consists of 40 percent sulfur trioxide by weight dissolved in sulfuric acid, are analogus. However oleum is more reactive than sulfuric acid. The mononitration is carried out in the first nitrator where the temperature is lowest and the mixed acid has the highest water content. The low temperature reduces the amount of meta and of ring oxidation products formed. Mononitration at -110°C followed by dinitration at 0°C to 25°C yields a product with one tenth the amount of these impurities as when nitration is carried out under normal conditions. This process, however, is much more costly than the one carried out at higher temperatures so is not used. Less degradation occurs because of the higher water content of the mixed acid.

Toluene is much easier to nitrate than benzene because of the presence of a methyl group compared with benzene. The reaction of introducing the first nitro group therefore proceeds very quickly, however the methyl group is readily oxidized. Mononitration also leads to oxidation of the ring and the formation of cresols. If the mixed acid is poor in nitric acid or if an insufficient amount of mixed acid is used, tar formation may take place. To counteract these undesirable effects an excess of mixed acid that is rich in nitric acid could be used. On the other hand, both excess HNO3 and excess mixed acid favor oxidation processes. Thus a trade-off must be achieved. Other oxidation reactions proceed especially readily under drastic conditions which introduce several nitro groups at a high temperature. This effect is minimized by having multiple nitrators with small temperature differentials between them. A concentration gradient for DNT and TNT exists across the production line. Table 8-54 shows the change in concentration of the nitro body, nitrated material in a six nitrator system. Six nitrators were used in the three Radford production lines before an explosion destroyed one of the lines. The explosion occurred during faulty manual removal of white compound which had coated the nitrator cooling coils. To stop the formation of white compound, an oxidation product, the number of nitrators was increased from six to eight. Each nitrator was also fitted with a centrifugal separator rather than a gravity separator, as the six original nitrators had. This reduced the amount of nitrobody in the system at any given time. Another design of continuous process in current use is the British ROF Process. This procedure also involves multistage countercurrent contacting, with the monoto-trinitration unit comprising a rectangular box-shaped vessel subdivided into eight stirred nitrator stages with intervening unstirred nitrobody-acid transfer sections. Mononitration is conducted separately in a smaller, similar vessel. This design desirably eliminates all interstage pipework and ductwork connections. This equipment applies to the use of 96 percent sulfuric acid, which requires more staging to affect complete nitration than in the case of the Radford plant, which employs 40 percent oleum. A comparison of the two systems shows that both give an 85 percent yield based on toluene, and that both have the same nitric acid requirement. Radford usage of sulfuric acid is about 79 percent that of the ROF process, calculating both on the basis of a strength of 96 percent. The ROF system employs a lower temperature for mononitration, 35°C to 42°C vs 50°C to 56°C for the Radford process. In West Germany, mononitration is affected by a continuous process, but di- and trinitration are conducted batchwise, because of a high purity requirement. Trinitration is affected with mixed acid comprising 24 percent HNO_3, 70 percent H_2SO_4, and 6 percent SO_3. The reaction requires six hours with slowly rising temperatures. These conditions remove the dinitrotoluene isomers more completely than is possible with the much shorter reaction time used in continuous operation.

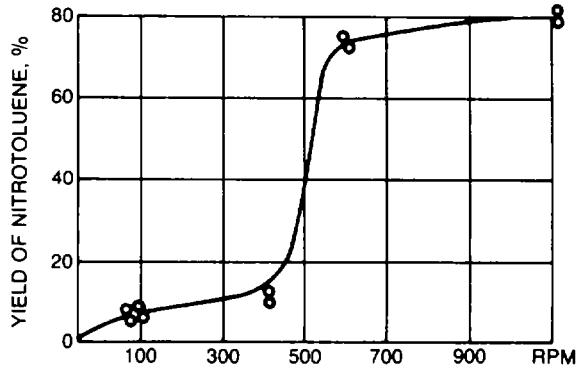


Figure 8-66. Agitation versus MNT yield.

(6) A problem associated with TNT production is the disposal of tetranitromethane (TNM), a toxic, odorous, and explosive material which is obtained in the exit gas from the trinitration step to the extent of about 136 grams to 227 grams per 45.4 grams of TNT. Venting TNM to the atmosphere is now illegal. The TNM can be recovered by scrubbing the gas with aqueous sodium carbonate containing stabilized hydrogen peroxide, which converts the TNM to nitroform. Nitroform is a raw material for making energetic plasticizers. Another objectionable effluent from TNT production is oxides of nitrogen (NOx). These can be removed (>95 percent) by oxidation to nitric acid, followed by scrubbing with sulfuric acid.

Table 8-54. Nitrobody Concentration for a Six Nitrator System

Nitrator	1	2	3	4	5	6
Temperature (°C)	50-55	70	80-85	90	95	100
Composition of nitrobody:						
MNT(°/o)	71.1%	-	-	-	-	-
DNT(%/o)	18.2	70.9	30.4	10.3	1.6	0.2
TNT(%/o)	4.2	28.9	69.3	89.5	98.2	99.7

(7) After nitration, the crude TNT requires purification. The ultimate objective of TNT purification is to remove all those products produced during nitration which are more reactive than TNT or which can easily give oily exudation products. Oil exudation from TNT is an undesirable characteristic for the following reasons:

(a) Exudation produces porosity of the TNT charge and the corresponding reduction in density. This reduces the explosive effect. In artillery shells this can produce a dislocation of the charge on firing, compression of the air included in the cavities, and premature explosion.

(b) The oily products can penetrate into the threaded parts of the shell and form "fire channels" through which the ignition of propellent can ignite the charge.

(c) The oily products can penetrate into the detonating fuze if the explosive of the fuze is not protected by a metal envelope, and reduce the detonating power of the fuze.

(8) Table 8-55 lists the impurities that are formed during the manufacture of TNT and the amounts contained in the product after purification. The concentrations listed in the table are maximum values; the actual values are lower.

Table 8-55. Impurities Present in TNT

Compound	Approximate maximum nominal concentration (%)	
	Crude	Finished
2,4,5-Trinitrotoluene	2.50	0.30
2,3,4-Trinitrotoluene	1.75	0.20
2,3,6-Trinitrotoluene	0.50	0.05
2,3,5-Trinitrotoluene	0.05	0.05
3,4,5-Trinitrotoluene	0.006	
2,6-Dinitrotoluene	0.25	0.25
2,4-Dinitrotoluene	0.50	0.50
2,3-Dinitrotoluene	0.05	0.05
2,5-Dinitrotoluene	0.10	0.10
3,4-Dinitrotoluene	0.10	0.10
3,5-Dinitrotoluene	0.01	0.01
1,3-Dinitrobenzene	0.02	0.02
1,3,5-Trinitrobenzene	0.15	0.10
2,4,6-Trinitrobenzyl alcohol	0.25	0.25
2,4,6-Trinitrobenzaldehyde	0.25	0.25
2,4,6-Trinitrobenzoic acid	0.50	0.50
Alpha-nitrato-2,4,6-trinitrotoluene	0.10	0.10
Tetranitromethane	0.10	none
2,2'-Dicarboxy-3,3',5,5'-tetranitroazoxybenzene (white compound)	0.35	0.05
2,2',4,4',6,6'-Hexanitrobibenzyl (HNBB)	none	0.40
3-Methyl-2',4,4',6,6'-pentanitrodiphenylmethane (MPDM)	none	0.40
3,3',5,5'-Tetranitroazoxybenzene	none	0.01

Of the TNT isomers formed, only the first two listed in the table, the 2,4,5- and 2,3,4-isomers, are present in significant quantities. The dinitrotoluenes result from incomplete nitration. The next eight compounds listed in the table result, directly or indirectly, from oxidation of the methyl group during nitration, while the last three are introduced during purification. The purification process currently in use involves treating TNT with aqueous sodium sulfite called sellite. The meta TNT isomers react with the sodium sulfite to form water-soluble sulfonates by the following reaction:

$$CH_3C_6H_2(NO_2)_3 + Na_2SO_3 \longrightarrow CH_3C_6H_2(NO_2)2SO_3Na + NaNO_2$$

Current American practice entails continuous treatment of molten TNT, at a temperature greater than 80°C, with an aqueous solution containing about 0.1 part anhydrous sodium sulfite per part TNT. This corresponds to about four times the theoretical requirement according to the equation given above. The liquids are countercurrently contacted in three washers each of which is followed by a centrifugal separator. This purification process is quite sensitive to pH. Yield loss rises sharply above pH 7.5 because of the formation of the water soluble complex of 2,4,6-TNT with sodium sulfite. In addition, at pH values above about 8 the formation of the two by-products hexanitrobibenzyl (HNBB) and methylpentanitrodiphenylmethane (MPDM) increases strongly. These compounds have an adverse effect on the mode of crystallization of TNT. Table 8-55 shows that meta TNT isomers are not completely removed and that the amounts of all of the DNT isomers and of five of the oxidation products remain unchanged. The ROF TNT Process also employs continuous purification, using a compartmented reactor generally similar to that used by them for nitration. However, the TNT is contacted as a solid at 67.5°C, rather than as a liquid, as in the American process. This is said to result in a higher yield of purer TNT with a requirement of about two-thirds as much sodium sulfite. HNBB and MPDM are not formed. Advantage is taken of the fact that the unsymmetrical isomers form a eutectic which migrates to the crystal surface. This type of process is also employed in West Germany. The process is operated batchwise using 4 to 10 parts Na_2SO_3 per 100 parts TNT with a reaction time of 30 minutes. Use of this purification procedure, taken with a batch trinitration method which removes nearly all of the DNT isomers, yields a TNT of unusually high purity. The solidification point of the product is 80.65°C to 80.80°C. This type of process has also been used in the past in the United States. Disposal of the waste sellite solution, known as red water, is a serious pollution control problem. TNT can be purified by recrystallization from nitric acid. This process has been used for many years in Sweden. The nitric acid, after crystallization and filtration of the 2,4,6-isomer, is recovered by distillation leaving a mixture consisting of about 50 percent 2,4,6-TNT, 25 percent TNT meta isomers, and 25 percent dinitrotoluenes and oxidation products known as isotrioil. The isotrioil is then sold as an ingredient in commercial dynamite. Sweden has had trouble marketing isotrioil, which is the major reason this otherwise attractive process has not been adopted elsewhere. Even after purification, military grade TNT typically shows 0.6 percent to 1.2 percent or more extrudate. A typical analysis of exudate from specification-grade TNT made in 1973 at the Radford Army Ammunition Plant by the continuous process is as follows:

2,4,6-TNT	88.19%
2,3,4-TNT	1.99%
2,4,5-TNT	0.67%
2,4-DNT	7.65%
2,6-DNT	0.98%
2,5-DNT	0.19%

HNBB and MPDM also form eutectics with TNT. Two approaches have been considered for minimizing extrudation. One approach to solving the extrudation problem is to produce TNT with smaller amounts of impurities. This can be done by carrying out nitration under more drastic conditions, which adds to the process cost, and closely controlling the sellite process to minimize production of HNBB and MPDM. Crystallization from nitric acid removes all DNT isomers. Another approach is to add materials to the TNT that absorb the eutectics. Cellulose esters, in the amount of about 0.6 percent, absorb the extrudate and reduce the tendency of the TNT to crack. Polyurethanes remove extrudate and double the compressive strength of the cast.

(10) Two types of TNT are specified for military use:

	Type I	Type II
Form	Flake or crystalline	Crystalline
Color	No darker than number 30257	Light yellow
Solidification point (°C), minimum	80.20	80.40
Moisture (%), maximum	0.10	0.10
Acidity (%), maximum	0.005	0.005
Alkalinity	None	None
Toluene insoluble matter (%), maximum	0.05	0.05
Sodium (%), maximum	0.001	0.001
Granulation		
through a US standard number 14 sieve	95	100
through a US standard number 100 sieve	-	95

For type I flake form the average thickness of the flakes shall not be more than 0.63 millimeters (0.025 inches) and any individual flake shall be no more than 0.1 millimeters (0.004 inches).

(11) TNT is one of the least sensitive of military explosives; only ammonium picrate, nitroguanidine, and ammonium nitrate are less sensitive. Impact tests yield high values relative to other military explosives, but impact sensitivity increases sharply with increasing temperature, as shown in table 8-56. Diminishing sensitivity has been reported down to- 196°C. Gap and projectile test results indicate cast TNT is less sensitive than the pressed materiel. Test results from the modified gap test for cast and pressed TNT are shown in table 8-57. Finely divided TNT, as obtained by fume condensation, is more sensitive to impact than the crystalline material. TNT which has been exposed to light is also more sensitive. The pendulum friction test does not affect TNT. The material is insensitive to rifle bullet impact at room temperature whether unconfined or confined in iron, tin, or cardboard bombs. The same results are obtained at the temperature between 105°C and 110°C with tin or cardboard bombs and in the iron bomb with an airspace. In an iron bomb with no airspace 70 percent of the trials resulted in explosions. The explosion temperature for unconfined TNT is 475°C which is much higher than for other commonly used military explosives. Explosion temperatures for confined samples depend on the purity of the sample and test conditions. Results in the range of 275°C to 295°C are obtained. Heating in a closed glass capillary tube yields a value of 320°C to 325°C. TNT has high minimum detonating charge values for initiation by lead azide or mercury fulminate. The dry material can be detonated by a number six electric blasting cap but the presence of only 7 percent moisture prevents detonation. This is compared to 14 percent and 35 percent moisture required for the desensitization of RDX and PETN respectively. TNT pellets pressed from flake TNT undergo substantial reductions in the rate of detonation and sensitivity to initiation after storage for one week at 65°C. These changes are accompanied by exudation of oily impurities, recrystallization, and sementation of the TNT. TNT is not classified as dangerous with respect to hazard from electric sparks. The sensitivity to electric discharge for 100 mesh TNT is 0.06 joules unconfined and 4.4 joules confined. The fine dust of TNT is sensitive to electric sparks. When ignited in free air, the dust burns completely without detonation; and the temperature of the liquid phase must be 510°C if detonation is to

Table 8-56. Impact Sensitivity of TNT

Temperature in °C	Inches on Picatinny Arsenal apparatus with 2 kilogram weight
-40	17
Room	14
80	7
90	3
05	2 (five explosions in 20 trials)

Table 8-57. Gap Test Results for TNT

	Density grams per cubic centimeter	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.651	0	3.96
	1.561	5.5	6.25
	1.353	18.0	7.90
LANL small scale gap test	1.633	1.3	0.33
	0.84	49.2	NO GO
	0.77	53.4	4.11
LANL large scale gap test	0.87 (flake)	47.4	37.1
	0.73 (granular)	55.9	60.8

result from burning. Even when it is under a gas pressure of 100 psi, the liquid phase temperature must be greater than 285°C if TNT is to burn with subsequent explosion. Figure 8-67 shows the results of trials of the Susan test for TNT.

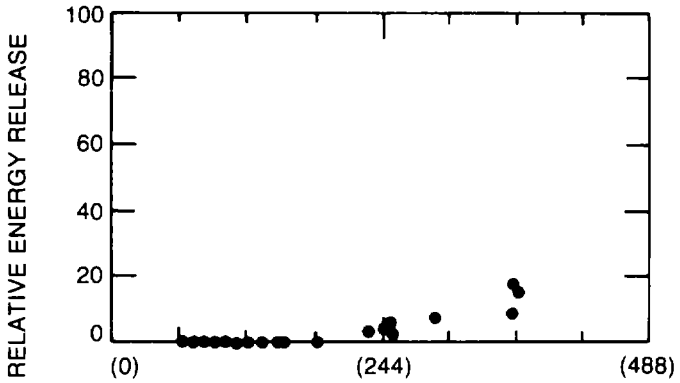


Figure 8-67. Susan test results for TNT.

(12) TNT is the standard explosive to which all the other explosives are compared. In the sand test, 48 grams of sand are crushed. The detonation velocity may be computed by the following equations:

$D=1.873+3.187p$ for $0.9 < p < 1.534$

$D=6.762+3.187(p-1.534)-25.1(p-1.534)^2$ for $1.534 < p < 1.636$

where D is in kilometers per second and p, the density, is in grams per cubic centimeter. Detonation velocities of stick charges can be substantially increased by the presence of an axial channel. The detonation temperature also increases with density. At densities of 1.0 and 1.59 grams per cubic centimeter the detonation temperature is 3,000°K and 3,450°K, respectively. The detonation pressure as a function of density is shown in table 8-58.

Table 8-58. Detonation Pressure of TNT

Density in grams per cubic centimeter	Detonation pressure in kilobars
1.59	202
1.63	190
1.64	190
1.65	222

In the copper and lead cylinder compression tests the cylinders are compressed 3.5 and 16 millimeters, respectively. The depth of the dent in the plate dent test is about 0.205 millimeters. The energy of detonation at 1.65 grams per cubic centimeter is 1,265 calories per gram or 4.10 joules per gram. At 1.62 and 1.64 grams per cubic centimeter 684 and 690 liters of gas are evolved, respectively. Fragmentation effects of pressed and cast TNT charges are shown in table 8-59.

Table 8-59. Fragmentation Effects of TNT

Density in grams per cubic centimeter	Pressed/cast	Average number of fragments produced	Average velocity of fragments in meters per second
1.54	pressed	1,070	3,620
1.58	cast	1,850	3,570

The Chapman-Jouguet particle velocity at 1.59 grams per cubic centimeter is 1.83 kilometers per second. The Von Neumann peak pressure at 1.614 grams per cubic centimeter is 237 kilobars. The critical charge diameter of stick charges of TNT is influenced by several factors including initial density, grain size, initial temperature, and degree of crystallivity. TNT cast with many crystallization centers, as is obtained by adding TNT seed crystals to the melt just before solidification, has a smaller critical diameter than that made by conventional crystallization from a clear melt. Cast and pressed charges of the same density have very different critical diameters. The reaction time of pressed TNT is less than half that of the cast material. Axially oriented TNT crystals show unstable detonation while radially oriented crystals detonate smoothly. TNT detonation products vary with the degree of confinement as shown in table 8-60. Increasing confinement shifts the formation of carbon monoxide to that of solid carbon, and the formation of hydrogen gas to that of water. The degree of conversion of the nitrogen atoms to elemental nitrogen remains consistent regardless of confinement.

Table 8-60. Effects of Confinement on TNT Detonation Products

Confinement	Product modes per mole of TNT						
	CO_2	CO	C(s)	N_2	H_20	H_2	NH_3
Heavily confined	1.25	1.98	3.65	1.32	1.60	0.46	0.16
Both ends of cylinder open	1.07	2.56	3.28	1.34	1.40	0.74	-
Unconfined	0.06	5.89	1.01	1.36	0.17	2.31	0.02

Trace amounts of methane, hydrogen cyanide, and ethane were also detected. In the Trauzl test, 10 grams of TNT expand the cavity by 285 to 305 cubic centimeters.

(13) TNT shows no deterioration after 20 years storage in a magazine or after two years storage as a liquid at 85°C. Only a small amount of decomposition occurs after storage at 150°C for 40 hours. Above that temperature slow decomposition occurs. Autoignition occurs after about 38 hours at 200°C. The thermal decomposition of liquid TNT is characterized by the sigmodial curve typical of an autocatalytic reaction. Explosions occur after an induction period that varies with temperature. However, heating at the boiling point causes distillation but not explosion in small samples. TNT vapor was found to undergo no decomposition over the range 250°C to 301°C at 35 to 500 torr. Even at 357°C the vapor does not explode although decomposition is quite extensive. As shown in figure 8-68, differential thermal analysis indicates an endotherm at 75°C to 100°C and an exotherm at 260°C to 310°C. The TGA curve is shown in figure 8-69. Although at least 25 products are formed, the major products obtained by heating a sample of TNT for 26 hours at 200°C are:

Unreacted TNT	75-90%
Explosive coke	0-13%
4,6-Dinitroanthranil	2-4%
2,4,6-Trinitrobenzaldehyde	1-2%
Azo and azoxy compounds	0.4%
2,4,6-Trinitrobenzyl alcohol	0.2%

The structure of 4,6-dinitroanthranil is shown in figure 8-70. The explosive coke is a brown, intractable powder, apparently polymeric, melting about 360°C, and containing nitro groups. The infrared spectrum indicates the presence of the nitro groups. Since similar results were obtained from heating TNT in a inert atmosphere and exposed TNT to air, oxidation must have occurred at the expense of nitro groups which would correspondingly be converted to azo or azoxy compounds or to an anthranil by inter- and intramolecular reaction, respectively, with the methyl groups. The most likely type of azoxy compound formed is shown in figure 8-71. Polymerization and crosslinking by reactions of this type can explain the formation of the explosive coke. The compound of the gases evolved was found to vary with the extent of reaction and with the temperature. The complicated nature of the process is shown by the fact that the evolved gases contain not only water, corresponding to the formation of the products cited above, but also CO, N_2, NO, N_20, and even acetylene. Rupture of the C-H bond in the methyl group is the rate determining step in thermal decomposition of TNT. The activation energy of thermal decomposition is 40.9±1.6 kilocalories per mole during the induction period and 30.2+0.6 kilocalories per mole for the post induction period. Added nitroaromatic compounds have no effect on the rate of thermal decomposition of TNT. Nitramine and aliphatic nitrated esters have only a slight effect. Strong promoters of decomposition include potassium nitrate, potassium chloride, certain iron and cobalt compounds, and ammonia. Other active compounds include: hydroquinone, benzoic acid, activated carbon, various plastic materials used to seal or line ordnance, trinitrobenzaldehyde, 4,6-dinitroauthranil and explosive coke. The last three compounds are thermal decomposition products of TNT. Aluminum oxide has a pronounced effect, while PbO, Fe, Al, and Fe_20_3 are less effective in that order, and Sn and CuO have little or no effect. Previous exposure to ultraviolet light for several hours also accelerates thermal decomposition. Moisture has no effect on the stability of TNT, which is unaffected by immersion in sea water. However, at 50°C ethanol reacts with alpha or gamma but not beta TNT. In case of alpha TNT the products are ethyl nitrite and an unidentified nitrocompound that melts at 77.5° to 77.9°C and is soluble in exudate oil.

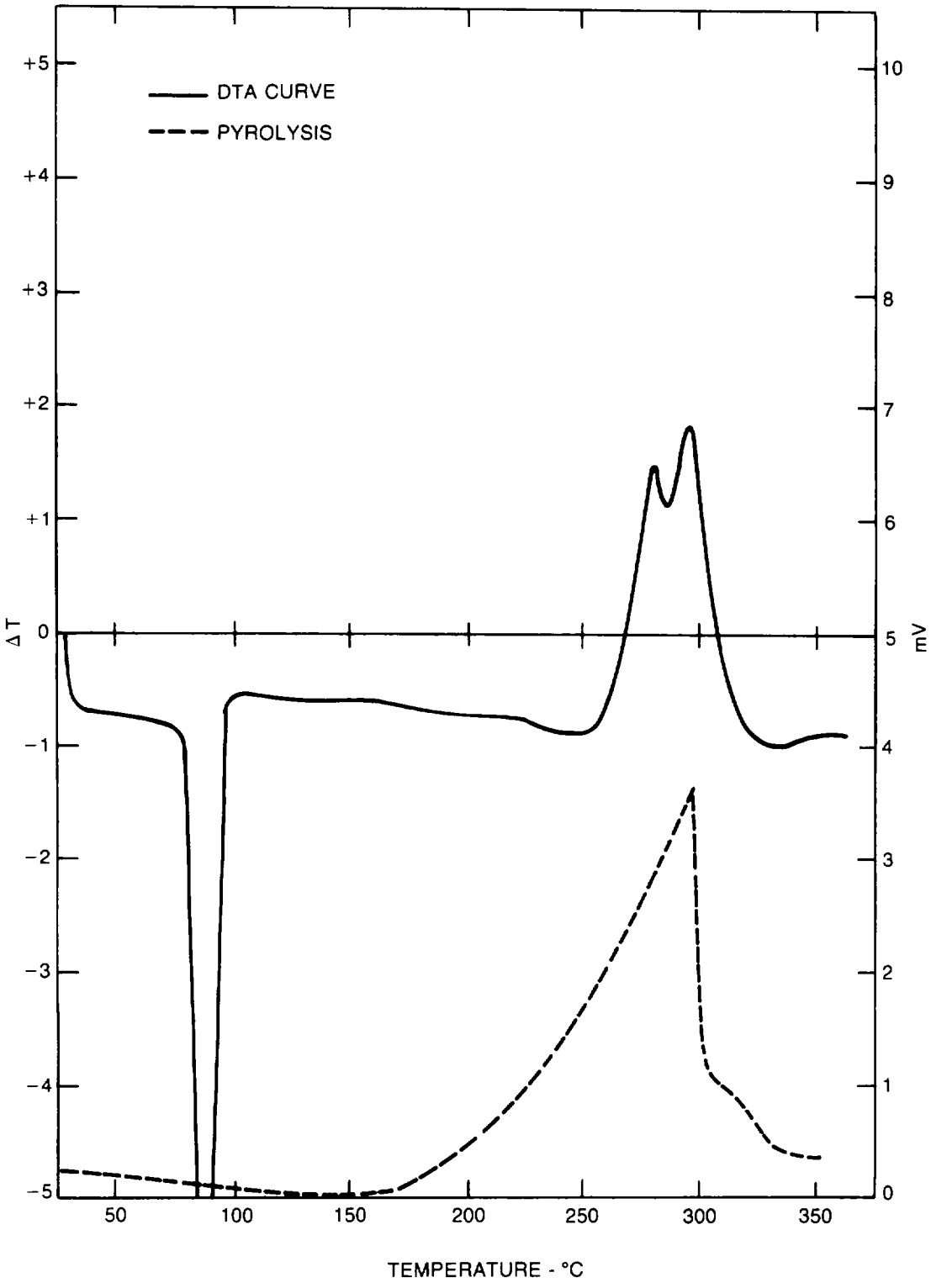


Figure 8-68. DTA curve for TNT.

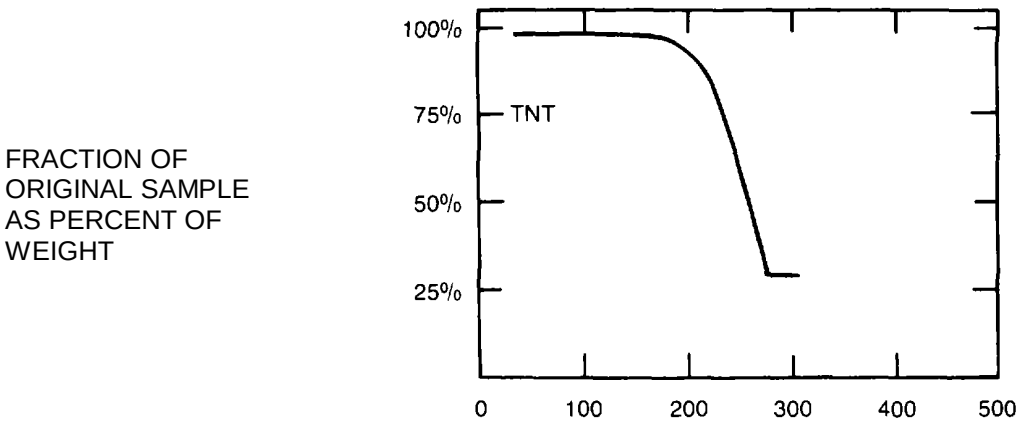


Figure 8-69. TGA curve for TNT.

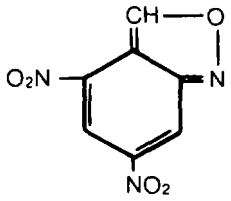


Figure 8-70. 4,6-Dinitroanthranil.

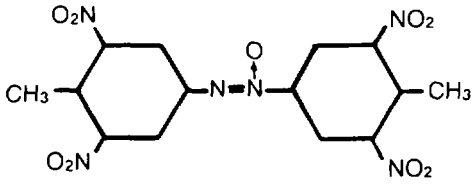


Figure 8-71. Explosive coke azoxy compound.

(14) Photolysis of aqueous solutions of TNT, such as the wastes obtained from munition plants, leads to the formation of pink water. Ultraviolet light excites the nitro group to a triplet state according to the equation:

$$ArNO_2 + \text{optical energy} \longrightarrow {}^3ArNO_2$$

Where Ar represents the aryl radical, which is the aromatic benzene ring with one hydrogen atom removed. The high energy triplet state extracts the hydrogen from the hydroxyl group of certain phenols according to the equation:

$$^3ArNO_2 + ROH \longrightarrow {}^3ArNO_2H + RO$$

This reaction is reversible and occurs with certain other nitro compounds. Flash photolysis of TNT entails intramolecular hydrogen abstraction from the methyl group by the ortho nitro group according to the reaction shown in figure 8-72. Reaction sequence (1) has been identified in nonpolar solvents. Reaction sequence (2) has been identified in solar or basic solvents. Photoexcitations of TNT at 215°C in the gas phase or at room temperature in certain solvents, especially dioxane, leads to the formation of 2,4,6-trinitrobenzyl free radicals. Ultraviolet irradiation of aqueous solutions of TNT has yielded a mixture of products, 15 of which have been identified. The methyl group has undergone reaction in all cases yielding one of the following compounds: an alcohol, an aldehyde, a carboxyl, or a derivative of one of these compounds. A nitro group has reacted in some cases, but this is always the ortho and never the para group to the methyl group. Solid TNT produces trinitrobenzoic acid upon exposure to light.

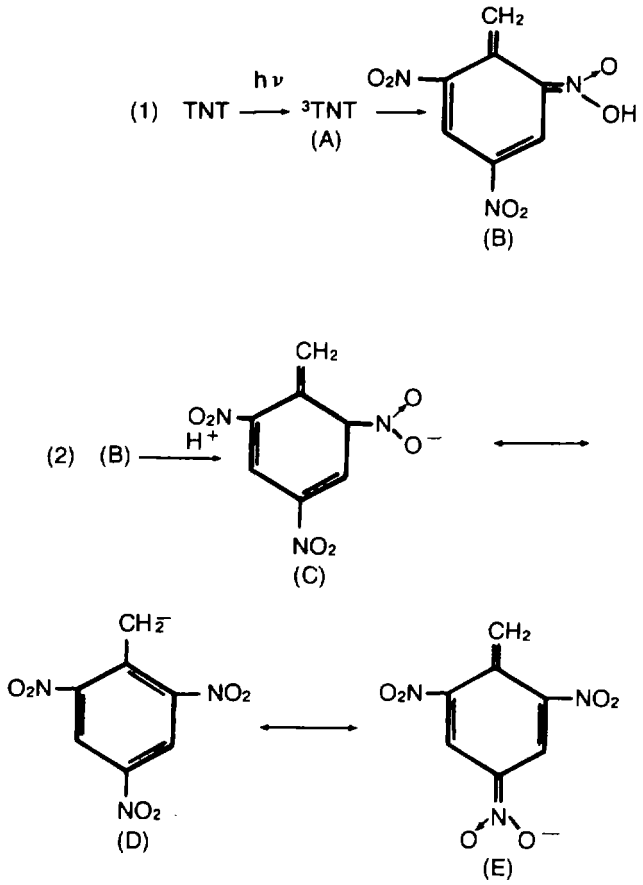


Figure 8-72. Photoexcitation of TNT.

8-5. Ammonium Nitrate.

a. Ammonium nitrate (figure 8-73) has a nitrogen content of 35 percent, an oxygen balance to H20 and N2 of 20 percent, and a molecular weight of 80.05. The crystal modifications of ammonium nitrate are shown in table 8-61.

Table 8-61. Crystal Modifications of Ammonium Nitrate

Form	Crystal system	Density in grams per cubic centimeter	Range °C
Liquid			Above 169.6
I Epsilon	Regular (cubic) (isometric)	1.58 to 1.61	125.0 to 169.6
II Delta	Rhombohedral or tetragonal	1.64 to 1.67	84.1 to 125
III Gamma	Orthorhombic	1.64 to 1.66	32.3 to 84.1
IV Beta	Orthorhombic	1.71 to 1.75	-18 to 31.2
V Alpha	Tetragonal	1.70 to 1.72	-18 to - 150

The density of the molten material in grams per cubic centimeter is 1.402 and 1.36 at 175°C and 200°C, respectively. When heated at atmospheric pressure, decomposition occurs at 230°C and deflagration occurs at 325°C. There may even be decomposition at temperatures as low as 100°C since constant weight cannot be obtained at this temperature and decomposition is quite perceptible above the melting point. The boiling point of the pure material is 210°C. Distillation without decomposition can be carried out at 11 torr. On the Mohs scale a scratch hardness of 1.1 is reported. Specific heat values as a function of temperature are listed in table 8-62.

Table 8-62. Specific Heat of Ammonium Nitrate

Temperature in °C	Specific heat in calories per gram per degree centigrade
- 200	0.07
-150	0.19
-100	0.30
- 80	0.35
- 50	0.37
0	0.40
50	0.414
100	0.428

The heat of fusion is 18.23 calories per gram. The heat of formation is 88.6 kilocalories per mole. Under constant pressure, the heat of combustion is 49.4 kilocalories per mole and at constant volume, the heat is 50.3 kilocalories per mole. At 25°C the latent heat of sublimation is 41.8 kilocalories per mole.

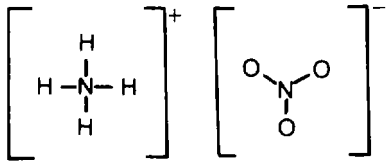


Figure 8-73. Structural formula for ammonium nitrate.

b. Ammonium nitrate can decompose according to any of the nine equations listed below. Unless otherwise stated, the heats of decomposition are based on solid phase ammonium nitrate. For molten ammonium nitrate add about 4,000 calories per mole to the values. The values for the heat liberated are at constant pressure and 18°C for solid ammonium nitrate with all decomposition products in gaseous form. None of these reactions occur as a single reaction, but are always accompanied by other reactions. The predominate reactions are the ones listed in (2) and the two listed in (7):

(1) $NH_4NO_3 \longrightarrow HNO_3+NH_3+38.30$ kilocalories. This reaction takes place at a temperature somewhat above the melting point of ammonium nitrate. The corresponding value for the solid salt is-41.70 kilocalories.

(2) $NH_4NO_3 \longrightarrow N_20+2H_20+13.20$ kilocalories with H20 gas and 33.10 kilocalories for H20 liquid. For the same reaction the value of-10.7 kilocalories has been reported. This reaction takes place in the temperature range of 180°C to 200°C when the ammonium nitrate is unconfined. Oxides other than N20 form at 203°C to 285°C. Decomposition at 260°C is accompanied by puffs of white smoke.

(3) $NH_4NO_3 \longrightarrow H_2+0.50_2+2H_20+30.50$ kilocalories for H20 gas or 50.40 for H20 liquid. For the same reaction, values from 27.72 to 30.50 kilocalories are reported for H20 gas. This reaction takes place when ammonium nitrate is heated under strong confinement or when initiated by a powerful detonator. This is the principal reaction of complete detonation of ammonium nitrate. According to calculations, this reaction develops an approximate temperature of 1,500°C and pressure of 11,200 kilograms per square centimeter. The gas evolved is calculated to be 980 liters per kilogram at standard temperature and pressure.

(4) $NH_4NO_3 \longrightarrow NO+0.5N_2+2H_20$ +9.0 kilocalories for H20 gas or 28.90 kilocalories for H20 liquid. A value of 6.87 kilocalories has also been reported for the reaction with the H20 gas. This may be one of the side reactions taking place during incomplete detonation. A pressure of 4,860 kilograms per square centimeter and a temperature of approximately 518°C are developed.

(5) $NH_4NO_3 \longrightarrow 0.5HN_3+0.75NO_2$ +0.25NO +0.25N2 + 1.25H20-21.20 kilocalories. This is a reaction of decomposition that occurs when ammonium nitrate is under confinement at 200°C to 260°C. This endothermic reaction is followed, at 260°C t 300°C, by explosion of the gaseous products of reaction. This explosion is an exothermic reaction liberating 48.49 kilocalories of heat which is more than 1.5 times as great as the heat liberated by reaction (3) above.

(6) $3NH_4NO_3 \longrightarrow 2N_2+N_20_3+6H_20+20.80$ kilocalories for H20 gas or 40.60 for H20 liquid. A value of 21.80 has also been reported for the reaction with the H20 gas. This reaction cannot take place alone because N203 exists only in the dissociated state as NO+ NO2.

(7) $4NH4NO_3 \longrightarrow 2NO_2+3N_2+8H_20+29.80$ kilocalories for H20 gas or 49.80 kilocalories for H20 liquid. A value of 24.46 has been reported for the reaction with the H20 gas. This is another possible side reaction occurring during incomplete detonation. For this reaction, a similar endothermic reaction can take place:

$$4NH_4NO_3 \longrightarrow 3NO_2+5H_20 + N_2+NH_3+NO$$
$$-84.88 \text{ kilocalories}$$

If the gaseous products are heated, an explosive exothermic reaction takes place.

(8) $5NH_4NO_3 \longrightarrow 2HNO_3+4N_2+9H_20$ +35.10 kilocalories for H20 gas or about 55 kilocalories for H20 liquid with HNO3 dissolved. This reaction takes place under certain conditions such as in the presence of spongy platinum and gaseous HNO3.

(9) $8NH_4NO_3 \longrightarrow 16H_20+2NO_2+5N_2$ +16.58 kilocalories. This reaction takes place during incomplete detonation and is accompanied by a yellow flame. The calculated value for the total gas developed by this reaction is 945 liters per kilogram.

c. Ammonium nitrate decomposed by strong alkalies liberates ammonia and decomposed by sulfuric acid forms ammonium sulfate and nitric acid. In the presence of moisture, ammonium nitrate reacts with copper to form tetraminocupric nitrate, Cu (NO3)2 4NH3, which has the same sensitivity to impact and brisance as lead azide. For this reason tools of brass and bronze are not used in operations with explosives containing ammonium nitrate.

d. Ammonium nitrate can be manufactured by several methods. The most common method is by passing ammonia gas into 40 percent to 60 percent nitric acid. Both the ammonia and nitric acid are produced by a catalytic process from atmospheric nitrogen, so the ammonium nitrate obtained is of very high purity. The solution is then concentrated in evaporating pans provided with air agitation and heating coils. To form ammonium nitrate crystals, one of three methods is used. One method involves transferring the material that has fudged in the evaporating pan to a flat grainer that is equipped with slowly rotating stainless steel paddles. Stirring in the open cools the syrup, drives off the remainder of the water and produces small, rounded crystals of ammonium nitrate. Another method involves transferring the solution, which has been concentrated to about 95 percent, from the evaporating pan to the top of a spraying tower. In the tower the solution is sprayed and allowed to fall where the remainder of the moisture evaporates and spherical grains, about the size of buck shot, of ammonium nitrate are formed. The grains are called prills. In the third method crystals are formed by vacuum evaporation at two torr, centrifuging, and drying to remove the remaining one to two percent moisture.

e. Ammonium nitrate used for military purposes must meet the following requirements:

Moisture:
Maximum, 0.15 percent.
Ether-soluble material:
Maximum, 0.05 percent.
Water-insoluble material of ether-extract:
Maximum, 0.10 percent.
Water-insoluble material:
Retained on a 250 micron (No. 60) sieve, none.
Retained on a 125 micron (No. 120) sieve.
Maximum, 0.01 percent.
Acidity, as nitric acid:
Maximum, 0.02 percent.
Nitrites:
None.
Chlorides, as ammonium chloride:
Maximum, 0.02 percent.
Phosphates, as diammonium phosphate:
0.21 ± 0.04 percent.
Sulfates, as diammonium sulfate:
0.007 to 0.014 percent.
Boric acid:
0.14±0.03 percent.
Ammonium nitrate:
Minimum, 98.5 percent.
Density:
Particle, g/ml.
Minimum, 1.50.
Bulk, g/ml.
Minimum, 0.80.
Bulk, Ibs/cu ft.
Minimum, 50.0.
pH:
5.9 ±0.2.

Granulation (percent by weight):
Through a 3360 micron (No. 6) sieve.
Minimum, 99.0.
Retained on a 1680 micron (No. 12) sieve.
50.0 - 85.0.
Retained on a 840 micron (No. 20) sieve.
Minimum, 97.0.
Through a 500 micron (No. 35) sieve.
Minimum, 0.5

The material must be free of nitrite and alkali. The granulation of ammonium nitrate is closely controlled so that satisfactory fluidity and density can be obtained in composition explosives.

f. Ammonium nitrate is the least sensitive to impact of any of the military explosives. Impact sensitivity varies with temperature as shown by the following data:

Temperature in °C	Impact height in inches (Picatinny apparatus)
25	31
100	27
150	27
175	12

The material is unaffected by the steel shoe in the pendulum friction test and does not explode in the five second explosion temperature test. Heating pure, unconfined ammonium nitrate produces a more or less rapid decomposition accompanied by a flash and a hissing sound but no explosions. If a crystal or a piece of cast ammonium nitrate is thrown upon a hot plate at a temperature of about 500°C, the material immediately catches fire and burns rapidly with a yellowish flame and a crackling or hissing sound, but leaves no residue. If a large piece of cast ammonium nitrate is thrown upon a red hot plate, the decomposition proceeds quickly enough to resemble an explosion. The minimum temperature at which a confined charge will explode is around 260°C to 300°C under a pressure of about 17,237 kilopascals (2,500 pounds per square inch). The sensitivity may be increased by the addition of powdered copper, iron, aluminum, zinc, chromium oxide, or chromium nitrate. Powdered limestone, kieselguhr, and clay reduce the sensitivity to heat. No explosions occur in the rifle bullet impact test. In the sand test, only partial explosion of ammonium nitrate results even if boosted with a charge of tetryl or RDX. Larger charges, when properly combined, can be detonated by means of a booster charge of tetryl but not by means of a lead azide or mercury fulminate blasting cap. If ammonium nitrate is unconfined, a number eight blasting cap will not cause complete detonation. The molten material is easier to initiate than the solid and the dry material easier to initiate than the moist. The sensitivity of ammonium nitrate to initiation decreases with increases in loading density. If the density exceeds 0.9, charges of one to three pounds cannot be detonated completely by large booster charges. Larger quantities cannot be detonated completely at densities greater than 1.1. The admixture of up to eight percent of nonexplosive carbonaceous material somewhat sensitizes ammonium nitrate to initiation.

g. The brisance of ammonium nitrate cannot be measured in the sand test because of a failure to completely detonate. The lead cylinder compression test indicates a brisance of 54 percent of TNT for a sample with a density of 1.3 grams per cubic centimeter. Ammonium nitrate has a very low ability to propagate a detonating wave. In unconfined charges that are long and small in diameter, the detonating wave dies out before reaching the opposite end of the cartridge. Ammonium nitrate has a very low velocity of detonation. Factors affecting the velocity of detonation are density, degree of confinement, charge diameter, particle size, strength of the initiating impulse, temperature of the sample, and the presence of certain impurities such as organic materials or oxidizable metals. The rate of detonation increases with decreasing particle size. A decrease in the apparent density of the charge and an increase in confinement causes an increase in the velocity of detonation. An increase in the temperature of the charge from 15°C to 140°C results in an increase of 400 meters per second in the rate of detonation. Within certain limits an increase in the strength of the initiating agent, the diameter of the charge, and presence of organic compounds or oxidizable metals can increase the rate of detonation. The velocity of detonation varies from 1,100 meters per second to 3,000 meters per second. The Trauzl test indicates ammonium nitrate is 75 percent as powerful as TNT and the ballistic mortar test indicates a power of 79 percent of TNT at a density of 1.0 grams per cubic centimeter.

h. The vacuum stability test at 150°C indicates ammonium nitrate is a very stable material even at that temperature. Heating for 100 days at 100°C causes no appreciable decomposition. Decomposition does not appear to begin until the compound melts. At 220°C nitrous oxide, water, and nitrogen are formed. High temperature decomposition is used to manufacture nitrous oxide. If an organic material such as cellulose is present, decomposition of the mixture begins at 100°C and is pronounced at 120°C. The DTA curve for ammonium nitrate is shown in figure 8-74 and the TGA curve is shown in figure 8-75. Admixture with TNT has little if any effect on the stability of ammonium nitrate at temperatures less than 120°C.

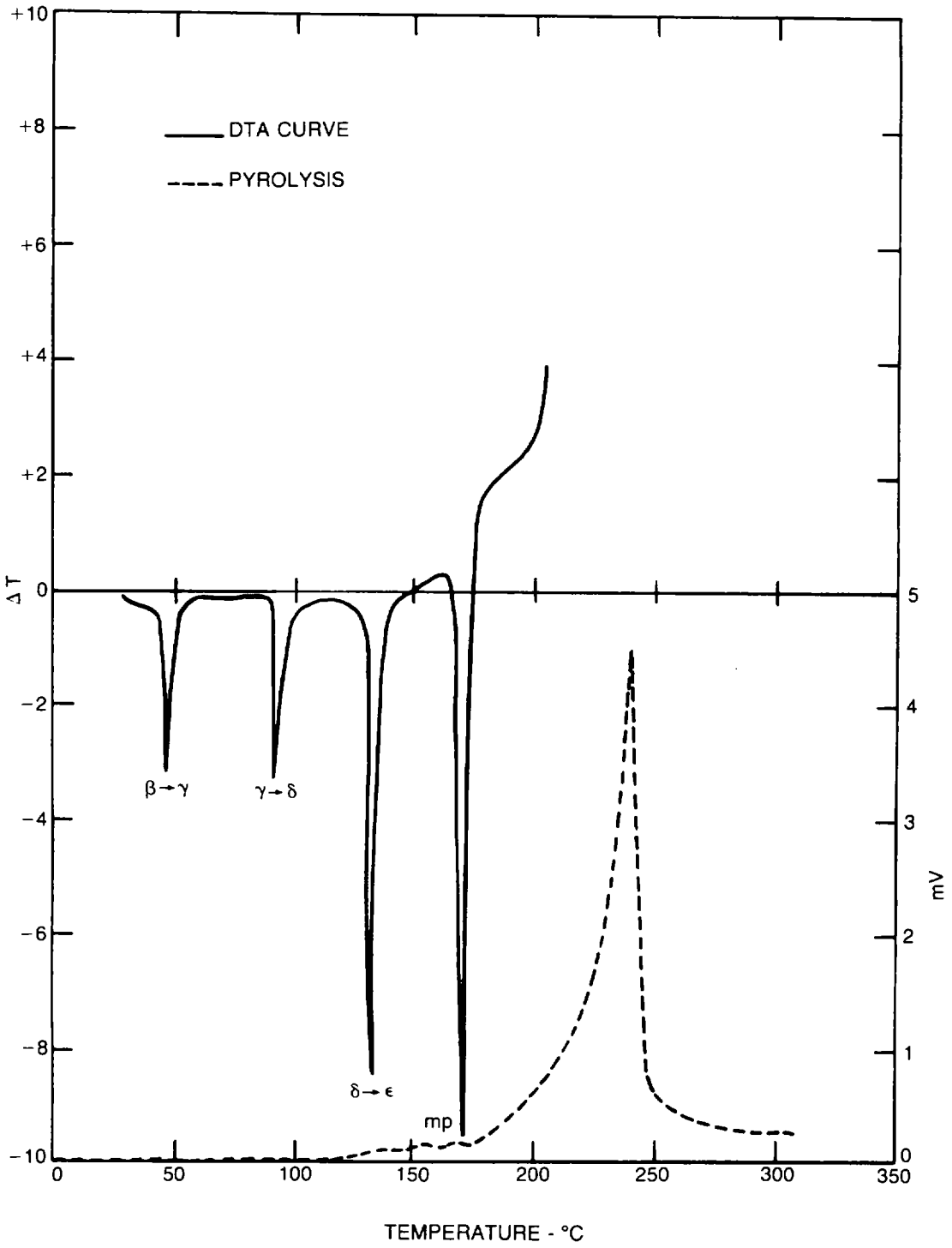


Figure 8-74. DTA curve for ammonium nitrate.

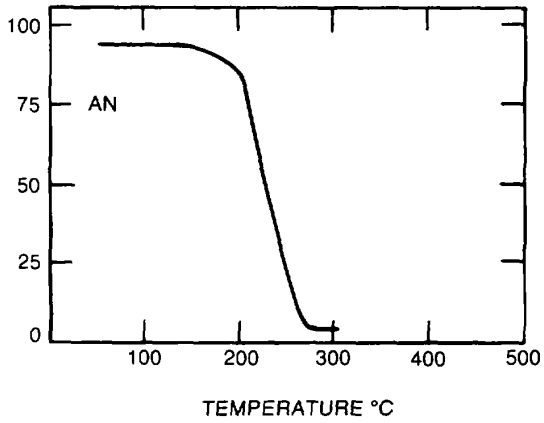


Figure 8-75. TGA curve for ammonium nitrate.

8-6. Compositions. Compositions are explosives in which two or more explosive compounds are mixed to produce an explosive with more suitable characteristics for a particular application. Generally, the characteristics of the composition are intermediate between the characteristics of the individual explosive ingredients. For example, the addition of TNT to RDX reduces brisance somewhat but considerably improves sensitivity. The composition explosives are categorized by the number of ingredients contained in the mixture.

a. Binary Mixtures.

(1) Amatols.

(a) Amatols are binary mixtures of ammonium nitrate and TNT. The percentages of ammonium nitrate and TNT are reflected in the nomenclature for each mixture, for example, 80/20 amatol consists of 80 percent ammonium nitrate and 20 percent TNT. Ammonium nitrate is insoluble in TNT. The chemical and physical properties of the constituents determine the properties of the amatol. The mixture begins to melt at TNT's melting point but the ammonium nitrate, which has a higher melting point, remains solid. The two ingredients may be dissolved separately. Table 8-63 compares the properties of some of the common amatol compositions. Amatols can be used for shell and bomb filling.

Table 8-63. Properties of Amatols

Properties	Amatol composition				
	80/20	60/40	50/50	45/55	40/60
Nitrogen content	31.7%	28.4%	26.8%	25.9%	25.1%
Oxygen balance to CO_2	+ 1.20%	- 17.6%	-27.0%	-31.7%	-36.4%
Oxygen balance to CO	+ 11.06%	+2.13%	-2.32%	-4.55%	-6.78%
Color	Lt buff	Lt buff	Buff	Buff	Buff
Melting point, °C	-	-	81	-	-
Heat of combustion at constant volume	1,254	-	2,073	-	2,402
Specific heat 20° to 80°C	-	-	0.383	-	-
Heat of detonation with liquid water at constant volume in kilocalories per gram	1,04-1,200	-	950	-	920

(b) 80/20 amatol is manufactured by heating ground and screened ammonium nitrate to 90° 95°C in a mixing kettle with a steam jacket. The ammonium nitrate cannot contain more than 0.25 percent water and must be finely granulated. The proper amount of molten TNT at 95°C is gradually added with mechanical agitation. The mixture is thoroughly blended by continuing the agitation at 95°C for at least 15 minutes after the TNT has been added. The mixture is then suitable for press loading or extrusion. The explosive is a plastic mass resembling wet brown sugar. Improper granulation of the ammonium nitrate can, on loading, cause separation of the molten TNT. To manufacture amatols with a 60 percent or less ammonium nitrate content, molten TNT is placed in the steam jacketed kettle. The screened and dried ammonium nitrate, which has been heated to 90° to 95°C, is added with agitation at a rate that prevents lumping. Agitation at 90° to 95°C is maintained until thorough blending and uniform fluidity are obtained. The temperature of the mixture is then reduced to 85°C for cast loading. The explosive resembles cast TNT.

(c) Impact tests indicate 80/20, 60/40, 50/50, and 40/60 amatols are 90 to 95, 95 to 100, 93 to 100, and 93 to 100 percent as sensitive as TNT, respectively. Amatols are unaffected by the rifle bullet impact test and the pendulum friction test. Explosion temperature test values for all the amatols are lower than that of TNT: 280°C to 300°C for 80/20 amatol, 270°C for 60/40 amatol, and 254°C to 265°C for 50/50 amatol. In the sand test 50/50 amatol is less sensitive to initiation than TNT, requiring a minimum charge of 0.05 gram of tetryl. However, 50/50 amatol can be detonated by diazodinitrophenol, and special tests have shown that less of this initiating agent is required to detonate cast or pressed 50/50 amatol than is required for cast or pressed TNT.

(d) Detonation characteristics for the amatols are listed in table 8-64. In the table, percentages are relative to TNT and density is given in grams per cubic centimeter.

Table 8-64. Detonation Characteristics of Amatols

	80/20 Amatol	60/40 Amatol	50/50 Amatol	40/60 Amatol
Brisance by sand test	74%	90%	90%	94%
Brisance by fragmentation test	-	81% at density of 1.53	82%at density	- of 1.55
Brisance by copper cylinder compression test	-	-	-	81% at density of 1.56
Power by Trauzl test	126%	-	116%	120%
Power by ballistic mortar test	130%	128%	123%	-
Detonation velocity in meters per second at 1.59 to 1.6 grams per cubic centimeter	5,300	6,200	6,400	6,550

Other experimental determinations of the velocity of detonation yields divergent results from those shown in the table, at least partially due to the variations caused by the granulation of the ammonium nitrate. Amatols have better oxygen balance than TNT producing larger amounts of gaseous explosion products. This accounts for the greater power of the amatols.

(e) The stability of 50/50 amatol is a little less than that of TNT at temperatures of 100° and 120°C as indicated by vacuum stability tests. There evidently is very slight reaction between TNT and ammonium nitrate at those temperatures. At temperatures below the melting point of TNT, there is no evidence of reaction. After storage at 50°C for three months, there is no change in the sensitivity, brisance, or stability of 50/50 amatol; and many additional months of such storage without effect might be anticipated. The DTA curve for 80/20 amatol is shown in figure 8-76. Amatols are hygroscopic due to the presence of the ammonium nitrate.

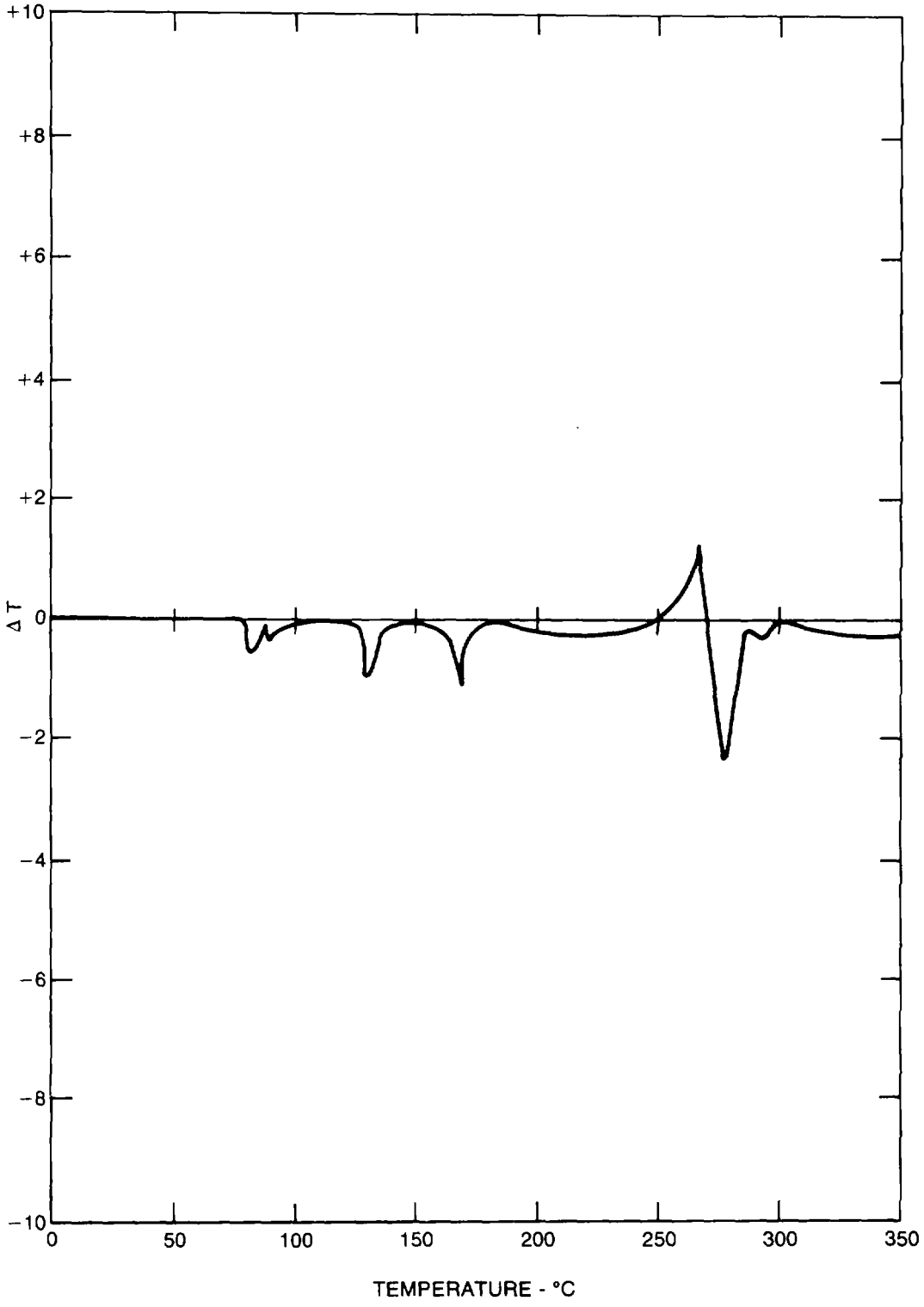


Figure 8-76. DTA curve for 80/20 amatol.

(f) 50/50 Amatol has an air blast energy of 84 percent of TNT, a water shock energy of 94 percent of TNT, and a shaped charge efficiency of 54 percent of TNT.

(g) Determination of the composition of amatol can be made by extracting a weighted sample with benzene, drying the residue, and weighing this. The weight of the residue is calculated to percentage of ammonium nitrate and the difference between this and 100 percent represents the percentage of TNT.

(2) Composition A.

(a) Composition A explosives consist of a series of formulations of RDX and a desensitizer. Table 8-65 lists the composition of the explosives. Compositions A and A2 contain the same percentages of materials as composition A3 but the type of wax used and the granulation requirements for the RDX are different. Composition A contains beeswax, while composition A2 contains a synthetic wax. Compositions A and A2 are no longer used. All of the composition A explosives are press loaded. The density of composition A3 is 1.47 and 1.65 grams per cubic centimeter when pressed to 20,685 kilopascals (3,000 pounds per square inch) and 82,740 kilopascals (12,000 pounds per square inch), respectively. Composition A3 may be completely dissolved in benzene and acetone, when these solvents are used successively. The color of the composition depends on the color of the particular desensitizer used. For composition A3 the heat of formation is-24.8 to - 28.4 kilocalories per gram and the heat of detonation is 1,210 kilocalories per gram.

Table 8-65. Composition A Explosives

	Ingredients in percent				
Composition	RDX	Desensitizing wax	Stearic acid	Polyethylene	Comments
A3	91.0±0.7	9.0±0.7	-	-	High explosive, projectile filler
A3 type 11	90.8±0.9	-	-	9.2±0.9	High explosive, projectile filler
A4	97.0±0.5	3.0±0.5	-	-	Boosters
A5 type 1	98.5±0.5	-	1.5±0.5	-	Shaped charges, grenades
A5 type 11	98.0 minimum	-	1.6 minimum	-	Also contains 0.4 percent lubricant
A6	86	14	-	-	Projectile filler

(b) The manufacture of composition A3 is carried out by heating a water slurry of RDX nearly 100°C and agitating. The wax, which contains a wetting agent, is added during agitation and agitation is continued while the mixture is allowed to cool to a temperature less than the melting point of the wax. After being caught on a filter, the composition is air-dried at 77°C.

(c) The relative impact sensitivity of composition A3 is 125 percent of TNT. There are no initiations in the rifle bullet impact test or pendulum friction test with either the steel or fiber shoe. The five second explosion temperature test result is 250°C to 280°C. In the booster sensitivity test, with material pressed to a density of 1.62 grams per cubic centimeter, detonations in 50 percent of the trials are caused by 100 gram tetryl pellets separated from the composition A3 by acrawax B pellets 4.318 centimeters (1.7 inches) thick. The minimum detonating charge of lead azide is 0.25 grams. The flammability index is 195 percent of TNT.

(d) The sand test indicates composition A3 is 107 to 115 percent as brisant as TNT and the plate dent test indicates 126 percent. In the fragmentation test a three inch shell containing 0.861 grams of composition A3 at a density of 1.64 grams per cubic centimeter produced 710 fragments versus 514 for the same weight of TNT. The fragment velocity at a distance of 2.75 meters (9 feet) is 853.44 meters per second (2,800 feet per second) and at a distance of 7.77 meters (25.5 feet) the fragment velocity is 771.14 meters per second (2,530 feet per second). The detonation velocity for a sample of composition A3 at a density of 1.62 grams per cubic centimeter is 8,100 to 8,200 meters per second. The Trauzl test and ballistic mortar indicate composition A3 is 144 percent and 135 percent of TNT, respectively.

(e) When subjected to the vacuum stability test for 48 hours at 100°C and 120°C composition A3 evolves 0.3 cubic centimeters of gas and 0.6 cubic centimeters of gas, respectively. These values are less for RDX, but slightly more for TNT. The 100°C heat test indicates that composition A3 undergoes volatilization. Composition A3 is nonhygroscopic, so is not affected by moisture during storage. Storage above 75°C is not recommended because of the softening effect on the wax coating. Figures 8-77 and 8-78 show the DTA curves for composition A and A3, respectively.

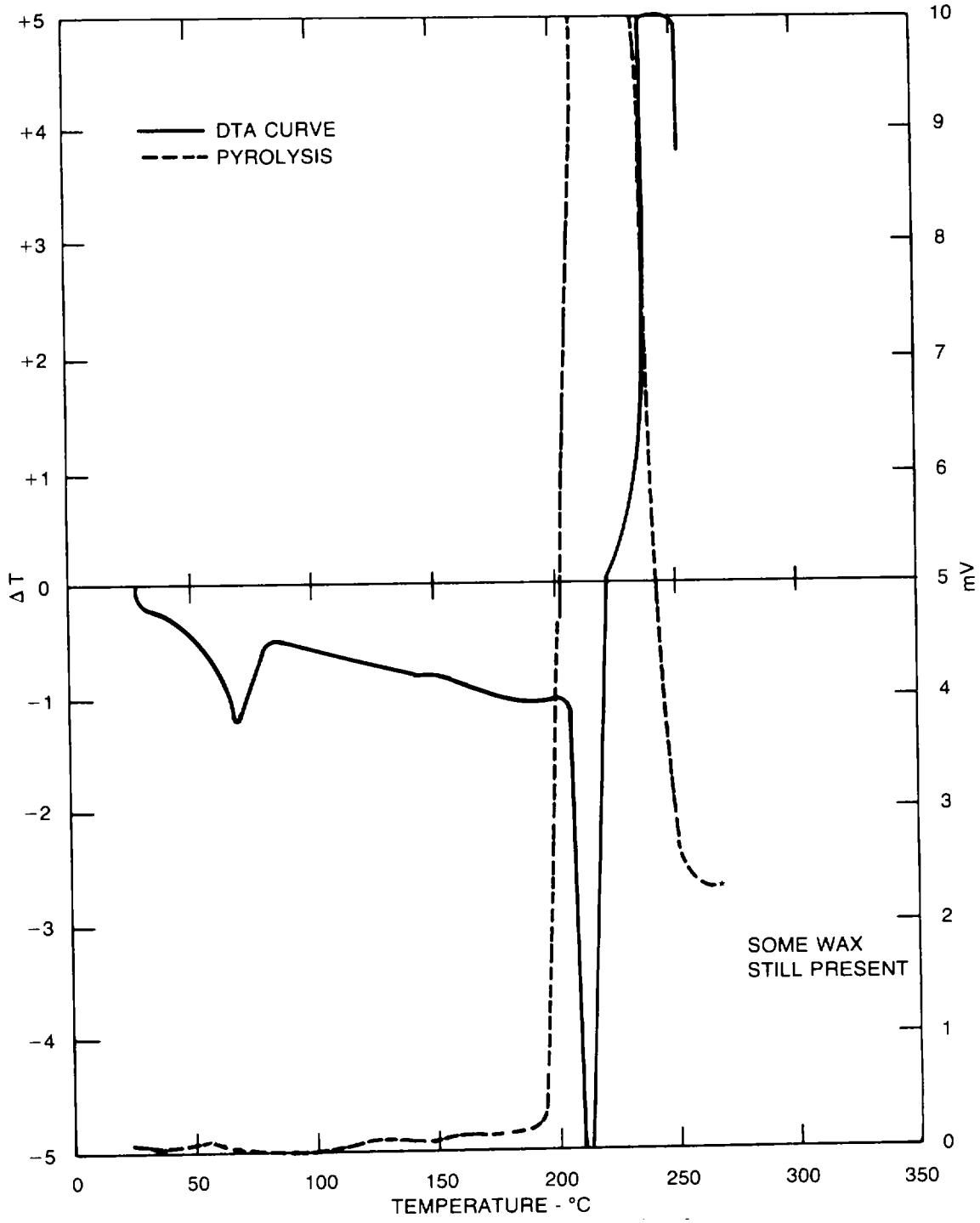


Figure 8-77. DTA curve for composition A.

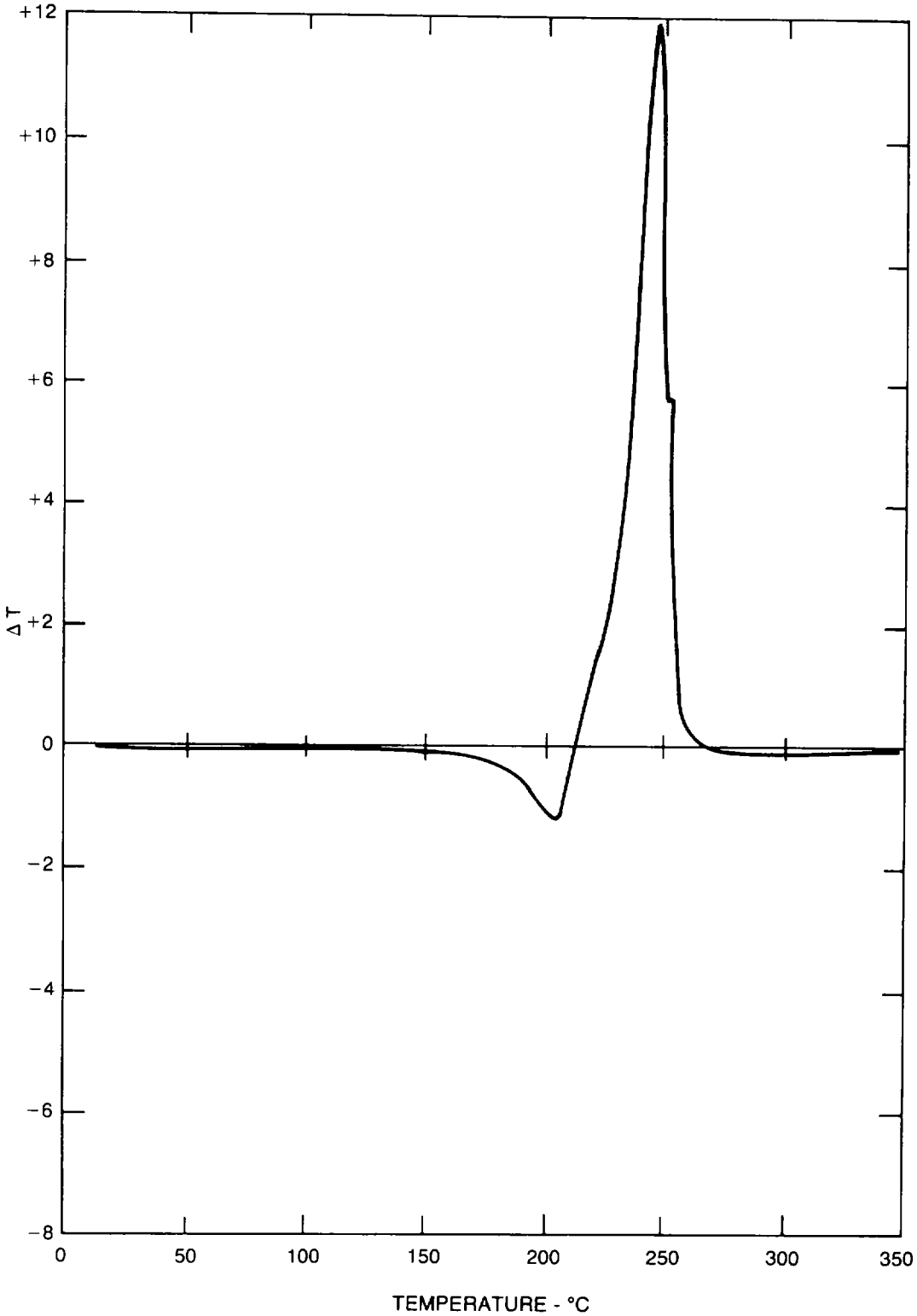


Figure 8-78. DTA curve for composition A3.

(3) Composition B.

(a) Composition B type explosives are mixtures of RDX and TNT. Composition B refers to mixtures of approximately 60 percent RDX and 40 percent TNT. Other portions of RDX and TNT are called cyclotols. Table 8-66 compares the properties of some composition B type explosives.

Table 8-66. Cyclotol Properties

Composition and properties	Cyclotol Type I	Cyclotol Type II A	Cyclotol Type II B	Compo-sition B	Compo-sition B2	Compo-sition B3
Percent RDX	75±2	70±2	69.6±2.0	59.5±2.0	60	59.9±1.0
Percent TNT	25±2	30±2	29.9±2.0	39.5±2.0	40	40.5±1.0
Percent wax	-	-	1±.03	-	-	-
Calcium silicate	-	-	0.5±0.15	-	-	-
Oxygen balance to $C0_2$,%	-35	-37		-43	-43	-
Color of material	Yel-buff	Yel-buff	-	Yel-brown	Yel-brown	-
Castability at 90°C poured	Difficulty poured	Difficulty	- poured	Easily poured	Easily	-
Thermal characteristics (in units of calories per gram):						
Heat of combustion	2,625	2,685	-	-	2,820	-
Heat of explosion	1,225	1,213	-	-	1,195	1,200
Heat of fusion	5.0	-	-	-	-	-
Impact sensitivity properties with 2 kilogram weight:						
Bureau of Mines apparatus	-	60	-	75	75	-
Picatinny Arsenal apparatus	-	14	-	14	14	-
Weight of sample in milligrams	-	20	-	19	19	-
Rifle bullet impact test:						
Percent explosions	30	30	-	3	5	-
Percent partials (smokes)	40	30	-	13	55	-
Percent burned	0	0	-	4	25	-
Percent unaffected	30	40	-	80	15	-
Sensitivity to initiation	-	LA 0.20	-	LA 0.20	LA 0.20	-
(minimum detonating charge in grams)	-	MF 0.21	-	MF 0.22	MF 0.22	-
Detonation characteristics:						
Brisance by plate dent test (percent TNT)	-	136	-	129 - 132	132	-
Brisance by sand test (percent TNT)	-	118	-	113	114	-
Fragmentation test:						
Number of fragments from 90mm HE, M71 shell	1,514	1,165	-	998	998	-
Weight of bursting charge in grams	1,008	1,005	-	993	993	-
Number of fragments from shell containing TNT	703	703	-	703	703	-
Fragment velocity in meters per second (feet per second)						
at distance 2.74 meters (9 feet)	-	-	-	896 (2,940)	903.7 (2,965)	-
at distance 7.77 meters (25 feet)	-	-	-	816.8	853.4	-

Table 8-66. Cyclotol Properties (Cont)

Composition and properties	Cyclotol Type I	Cyclotol Type II A	Cyclotol Type II B	Compo-sition B	Compo-sition B2	Compo-sition B3
The value for TNT at 2.24 meters is 792 meters per second and at 7.77 meters is 719 meters per second.	-	-	-	(2,680)	(2,800)	-
Detonation rate in meters per second at room temperature for 2.54 centimeter diameter charge						
(d in grams per cubic	8,252	8,060	-	7,840	7,900	-
centimeter)	at d 1.743	at d 1.73	-	at d 1.68	at d 1.72	-
Gas volume in cubic centimeters per gram	862	854	-	-	845	-
Stability tests:						
Heat test at 100°C:						
Percent loss in 1st 48 hours	0.07	-	0.2	-	-	-
Percent loss in 2nd 48 hours	-	0.08	-	0.2	-	-
Explosion in 100 hours	-	None	-	None	-	-
Hygroscopicity in percent at 30°C and 900/o relative humidity	-	Nil	-	0.02	Nil	-
Vacuum stability test results in cubic centimeters evolved in 48 hours:	0.23	-	-	0.7	-	-
at 100°C	0.41	0.86	-	0.9	0.29	-
at 120°C	-	-	-	11 +	-	-
at 150°C						
Blast effect in air as a percent of TNT:						
Peak pressure	111	110	-	110	104	-
Impulse	126	120	-	110	116	-
Energy	-	-	-	116	-	-
Shaped charge effectiveness as a percent of TNT:						
Hole volume with glass cones	-	-	-	178	178	-
Hole volume with steel cones	-	-	-	162	162	-
Hole depth with glass cones	-	-	-	125	125	-
Hole depth with steel cones	-	130	-	148	148	-

(b) Composition B grade A is formulated as a 60/40 RDX/TNT mixture, but high quality castings usually are higher in RDX content because a TNT rich section is removed from the top of the casting. The casting has a nominal formulation of 36 percent TNT, 63 percent RDX, and 1 percent wax. The grade A composition B is also made from grade A RDX. The theoretical maximum density of both grades A and B composition B is 1.737 grams per cubic centimeter, the open melt density is 1.68 to 1.70 grams per cubic centimeter, and the vacuum melt density is 1.715 to 1.720 grams per cubic centimeter. The theoretical maximum density of composition B3 is 1.750 grams per cubic centimeter and the vacuum melt density is 1.725 to 1.730 grams per cubic centimeter. 75/25 Cyclotol has a theoretical

maximum density of 1.776 grams per cubic centimeter and a vacuum melt density of 1.74 to 1.75 grams per cubic centimeter. 70/30 Cyclotol has a theoretical maximum density of 1.765 grams per cubic centimeter and an open melt density of 1.71 to 1.73 grams per cubic centimeter.

(c) RDX is slightly soluble in molten TNT and the two compounds form an eutectic mixture that freezes at 79.0°C and contains 95.84 percent TNT and 4.16 percent RDX. When heated, RDX undergoes some softening at a relatively low temperature because of the melting of the wax present and further melting at the eutectic temperature. As the temperature is increased, some of the RDX is dissolved and at 100°C there are in equilibrium 42.8 parts of molten solution and 57.2 parts of solid RDX. The viscosity of composition B as cast is an important characteristic that is affected markedly by the granulation of the RDX and the nature of the wax used, the wax causing an increase in the viscosity. Representative viscosity values for composition B at 83° and 95°C are 3.1 and 2.7 poises, respectively.

(d) Composition B is manufactured from TNT and water wet RDX. The TNT is melted at approximately 100°C in a steam jacketed melting kettle equipped with a stirrer. The damp RDX is added slowly with stirring, and after addition of the RDX is completed, most of the water is poured off and heating and agitation are continued until all moisture has been driven off. The wax is then added and mixed thoroughly with the other ingredients by stirring. The nature of the wax is important since only certain waxes mix with the RDX and TNT and do not tend to segregate during cooling. The thoroughly mixed composition B then is cooled with continued agitation until the fluidity is satisfactory for casting. The composition B is either cast directly into bombs or solidified into chips approximately 4.8 square centimeters by .6 centimeters. The chips are produced when the composition B is to be stored or shipped for use elsewhere.

(e) Impact sensitivity for solid composition B is between that of TNT and RDX. Cast composition B is more sensitive than the powdered material. As judged by the pendulum friction test, powdered composition B is no more sensitive than TNT, and at 100°C the two explosives show no increase in sensitivity to friction. Like TNT, cast composition B can be drilled without undue hazard. The explosion temperature test value of composition B (270°) is only slightly greater than that of RDX, but the sensitivity of composition B to electrical sparks is more nearly that of TNT than that of RDX. Composition B is intermediate between TNT and RDX in sensitivity to initiation. Cast composition B is somewhat less sensitive to initiation than the pressed material. Table 8-67 lists the gap test results for composition B.

(f) Composition B3 behaves reasonably well in the Susan test. Ignition occurs at the beginning of the pinch stage only after extensive splitting and deformation of the nose cap. The threshold velocity is about 55 meters per second. The reaction level as a function of projectile velocity is shown in figure 8-79. Even at 457 meters per second the full potential of the reaction is not released. These results indicate composition B3 is difficult to ignite by mechanical means and has a low probability for violent reactions once ignited, provided confinement is light. Composition B3 has been observed to detonate in impact geometries where there was good inertial confinement at the time of ignition and where the impact subjected the charge to mechanical work.

Table 8-67. Gap Test Results for Composition B

	Density	Percent voids	Sensitivity in millimeters
LANL small scale gap test:			
Composition B, grade A	1.710 (cast)	1.1	0.41 - 0.66
Composition B3	1.721 (cast)	1.8	1.1 - 1.4
75/25	1.753 (cast)	1.1	0.25 - 0.41
LANL large scale gap test:			
Composition B, grade A	1.712 (cast)	2.2	44.58
Composition B3	1.727 (cast)	1.4	50.34
75/25 Cyclotol	1.757 (cast)	0.6	43.15
	1.734 (cast)	2.2	45.74
PX gap test:			
Composition B	1.714 (cast)	2.2	2

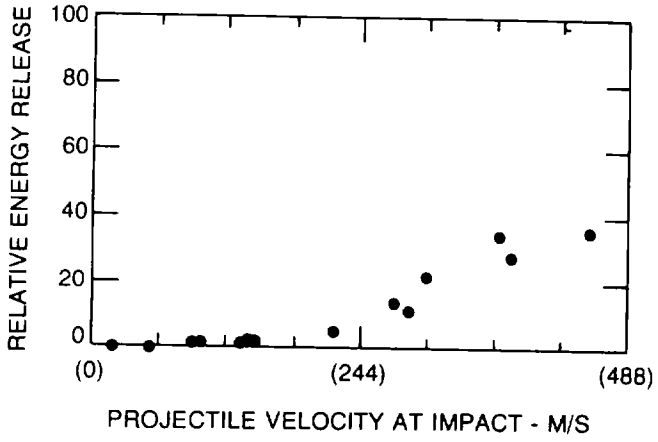


Figure 8-79. Susan test results for composition B3.

(g) 75/25 Cyclotol has both good and bad properties, as measured by the Susan test. The reaction level as a function of projectile velocity is shown in figure 8-80. The threshold velocity for a reaction is about 55 meters per second. This value is typical of TNT bonded cast explosives and higher than most plastic bound explosives. On the other hand, reaction levels are moderately high at relatively low velocities and on occasion are considerably higher. 75/25 Cyclotol is considered relatively difficult to ignite by mechanical means but capable of a large reaction once ignited.

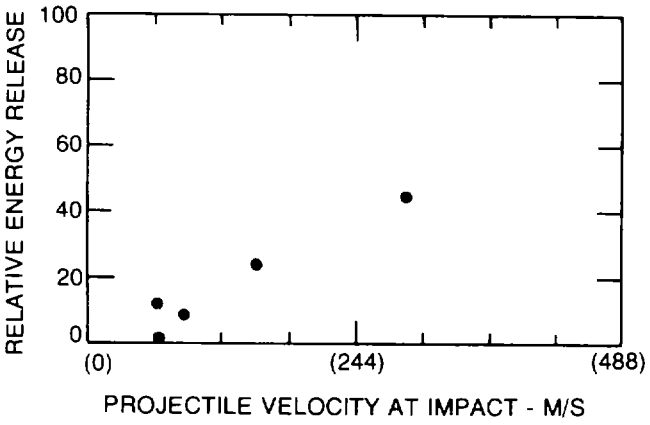


Figure 8-80. Susan test results for 75/25 cyclotol.

(h) Grade A composition B with a density of 1.713 grams per cubic centimeter and 64 percent RDX by weight has a detonation velocity of 8,018 meters per second and a detonation pressure of 292.2 kilobars. Cyclotol with 77 percent RDX by weight with a density of 1.743 grams per cubic centimeter has a detonation pressure of 312.5 kilobars.

(i) Storage of composition B at 75°C for one month causes no decrease in stability. Storage at 65°C for over one year causes no change in acidity, sensitivity to impact, or brisance. However, five months of such storage causes slight exudation. If the composition B is made from TNT which has a freezing point of 80.710C, slight exudation occurs at a storage temperature of 710C. Composition B, therefore, is of a high order of chemical stability but should not be stored at too elevated a temperature because of physical instability at such temperatures. Composition B reacts slightly with rust at 100°C. At ordinary temperature, dry composition B causes very slight corrosion of copper and brass but does not affect aluminum, mild steel, stainless steel, nickel, cadmium, or zinc. In the presence of 0.5 percent moisture, composition B causes some corrosion of cadmium and zinc also.

(j) The RDX content of composition B can be determined by extracting a weighed sample with benzene saturated with RDX, drying the residue, and calculating the weight of this to percentage of RDX. The desensitizer content is determined by extracting another weighed sample with acetone cooled to 5°C, drying the residue, and calculating the weight of this to percentage of desensitizer. The percentage of TNT in the composition is obtained by subtracting from 100 the sum of the percentages of RDX, desensitizer, and moisture found present.

(k) Composition B2 is not a standard explosive. Differing from composition B only in the absence of wax, composition B2 has a greater density when cast and is slightly more brisant. The detonation velocity is also slightly higher. Composition B2 is distinctly more sensitive than composition B, as judged by large scale impact and rifle bullet impact tests, and is slightly more sensitive to initiation. The two compositions are of the same stability and hygroscopicity. Greater impact sensitivity makes composition B2 less suitable than composition B for use in bombs.

(l) The DTA curves for composition B and 75/25 cyclotol are shown in figures 8-81 and 8-82, respectively. The TGA curve for composition B is shown in figure 8-83.

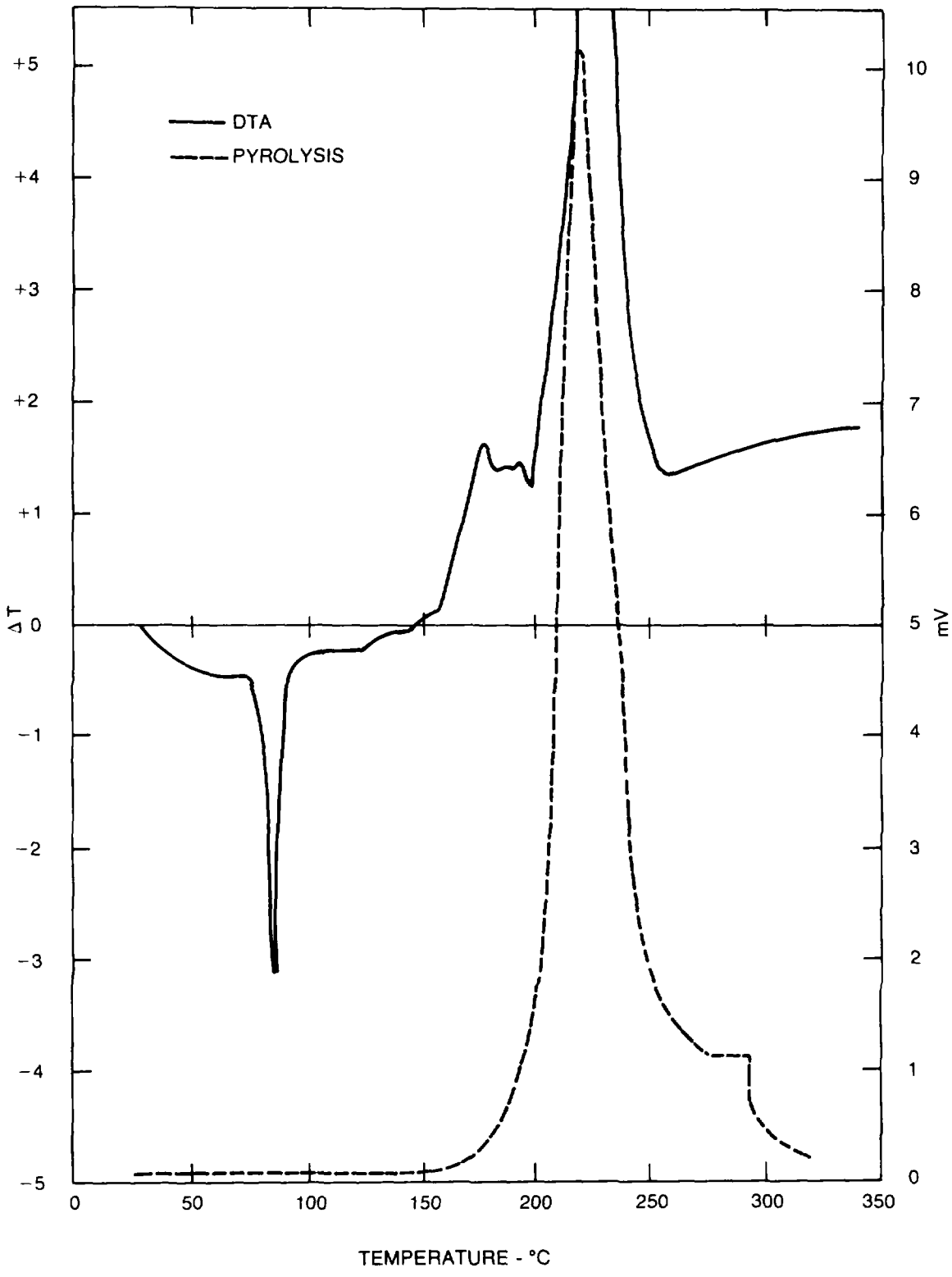


Figure 8-81. DTA curve for composition B.

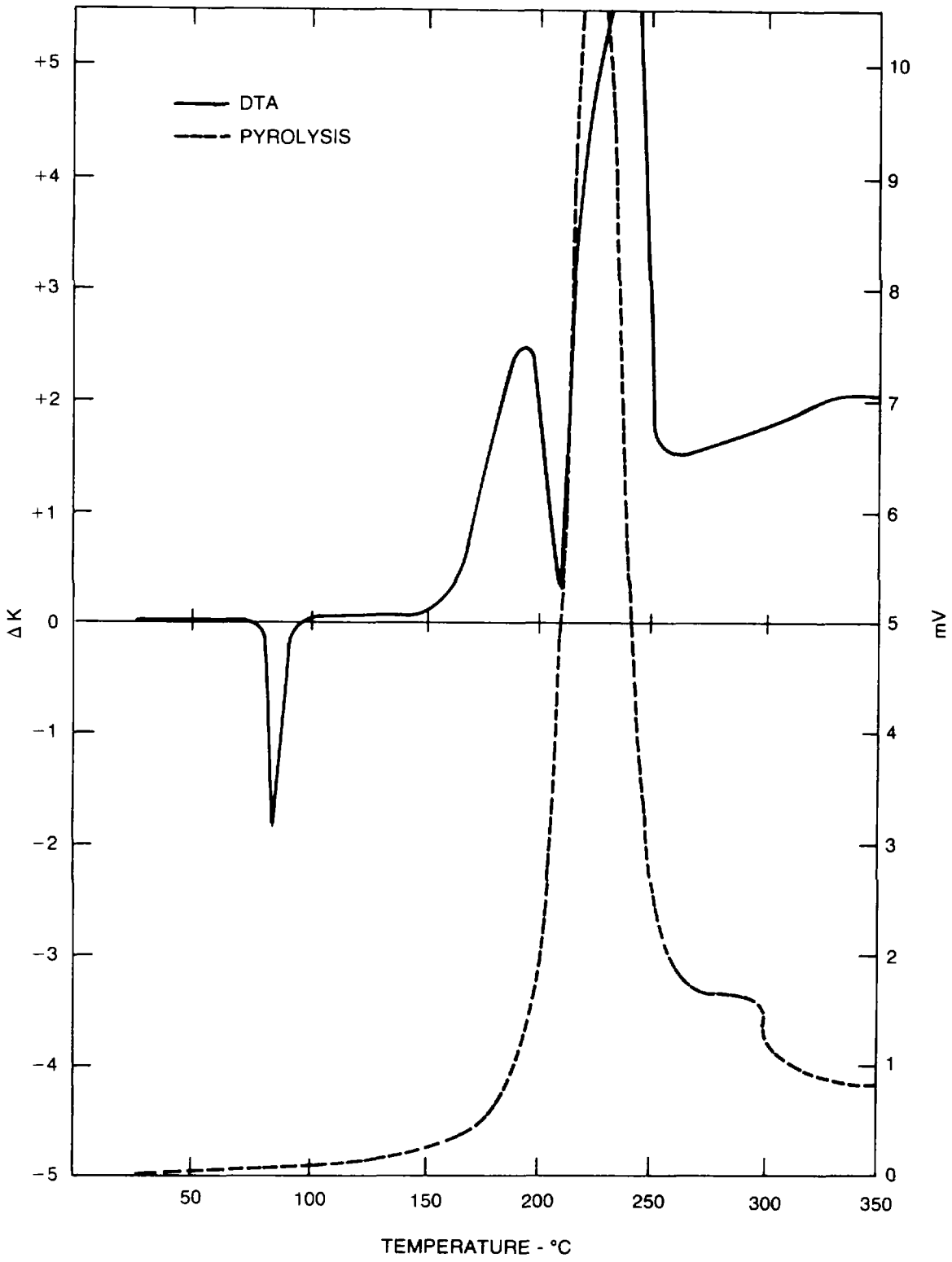


Figure 8-82. DTA curve for 75/25 cyclotol.

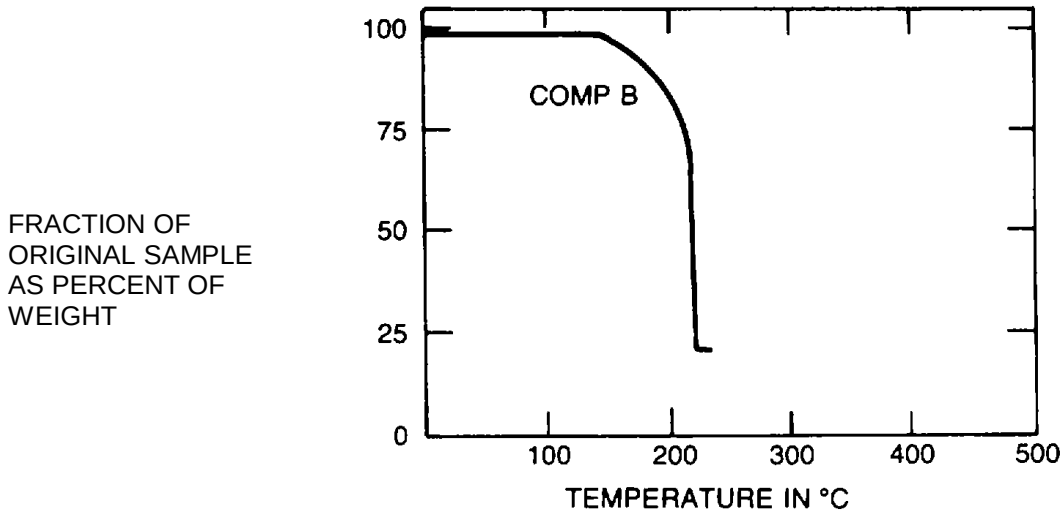


Figure 8-83. TGA curve for composition B.

(4) Composition C.

(a) During World War II, the British used a plastic demolition explosive that could be shaped by hand and had great shattering power. As standardized by the United States, this explosive was designated as composition C and contained 88.3 percent RDX and 11.7 percent of a nonexplosive oily plasticizer. Included in the plasticizer was 0.6 percent lecithin, which helped to prevent the formation of large crystals of RDX which would increase the sensitivity of the composition. Composition C was plastic from 0° to 40°C, but became brittle and less sensitive below 0°C and tended to become gummy and exude oil at temperatures above 40°C. Composition C was replaced by composition C2 which contained 80 percent RDX and 20 percent explosive plasticizer. This explosive plasticizer was composed of mononitrotoluene, a liquid mixture of dinitrotoluenes, TNT, nitrocellulose, and dimethylformamide. Composition C2 remained plastic from -30° to 52°C, but became less plastic in hot storage because of evaporation of volatile matter. Composition C2 has been replaced by composition C3, which contains 77 ± 2 percent RDX and 23 ± 2 percent explosive plasticizer. The plasticizer contains mononitrotoluene, a liquid mixture of dinitrotoluenes, TNT, tetryl, and nitrocellulose. It is a yellowish, puttylike solid that has a density of 1.60 and is soluble in acetone.

(b) In the manufacture of composition C3, the mixed plasticizing agent is placed in a steam jacketed, melting kettle equipped with a stirrer and heated to nearly 100°C. Water wet RDX is added slowly, and heating and stirring are continued until a uniform mixture has been obtained and all the water has been driven off. The mixture then is cooled while being agitated.

(c) One grade of composition C3 is manufactured. This grade includes two classes that differ only in acidity. Both class A and B material is used for the manufacture of demolition blocks, and class B explosive is also used in the loading of ammunition in which lower acidity is desirable. The requirements applicable to composition C3 are as follows:

Composition:
RDX plus nitrocellulose, 78.0±2.0 percent.
Plasticizer minus nitrocellulose, 22.0±2.0 percent.
Moisture:
Maximum, 0.25 percent.
Acetone insoluble material:
Maximum, 0.15 percent.
Inorganic acetone insoluble material:
Maximum, 0.05 percent.
Grit:
Maximum particles per 50 gram sample
Retained on No. 40 sieve, none.
Retained on No. 60 sieve, 5.
Plasticity:
Minimum extension in length at 250 to 30°C, 90 percent.
Acidity:
Class A maximum, 0.064 percent
Class B maximum, 0.05 percent

(d) Composition C3 is of the same sensitivity to impact as TNT and is not exploded in the pendulum friction test. The rifle bullet impact test produces partial explosions in 40 percent of the trials, which indicates greater sensitivity than that of TNT but much less sensitivity than that of RDX. The five second explosion temperature test value, 280°C, is only slightly greater than that of TNT. Composition C3 is less sensitive to initiation than TNT, requiring a minimum detonating charge of 0.08 gram of tetryl or 0.20 gram of lead azide in the sand test. Storage for four months at 65°C in an atmosphere of 95 percent relative humidity does not impair the sensitivity to initiation. In the booster sensitivity test 50 percent detonations are produced by 100 grams of tetryl separated from pressed composition C3 with a density of 1.62 grams per cubic centimeter by acrawax B pellets 3.45 centimeters thick.

(e) The chemical stability of composition C3 is acceptable, but the physical stability is not entirely satisfactory. The results of the 120°C heat test are: 3.20 percent loss in the first 48 hours, 1.63 percent in the second 48 hours, and no explosions in 100 hours. Composition C3 is volatile to the extent of a 1.15 percent weight loss when exposed to air at 25°C for five days, and hygroscopic to the extent of 2.4 percent when exposed to air with 90 percent relative humidity at 30°C. Tests have shown composition C3 to be of unimpaired brisance after immersion in water for 24 hours. Storage at 77°C causes considerable exudation. In vacuum stability tests at 100°C and 120°C for 48 hours, 1.21 and 11 + cubic centimeters of gas are evolved, respectively. Figure 8-84 shows the DTA curve for composition C3.

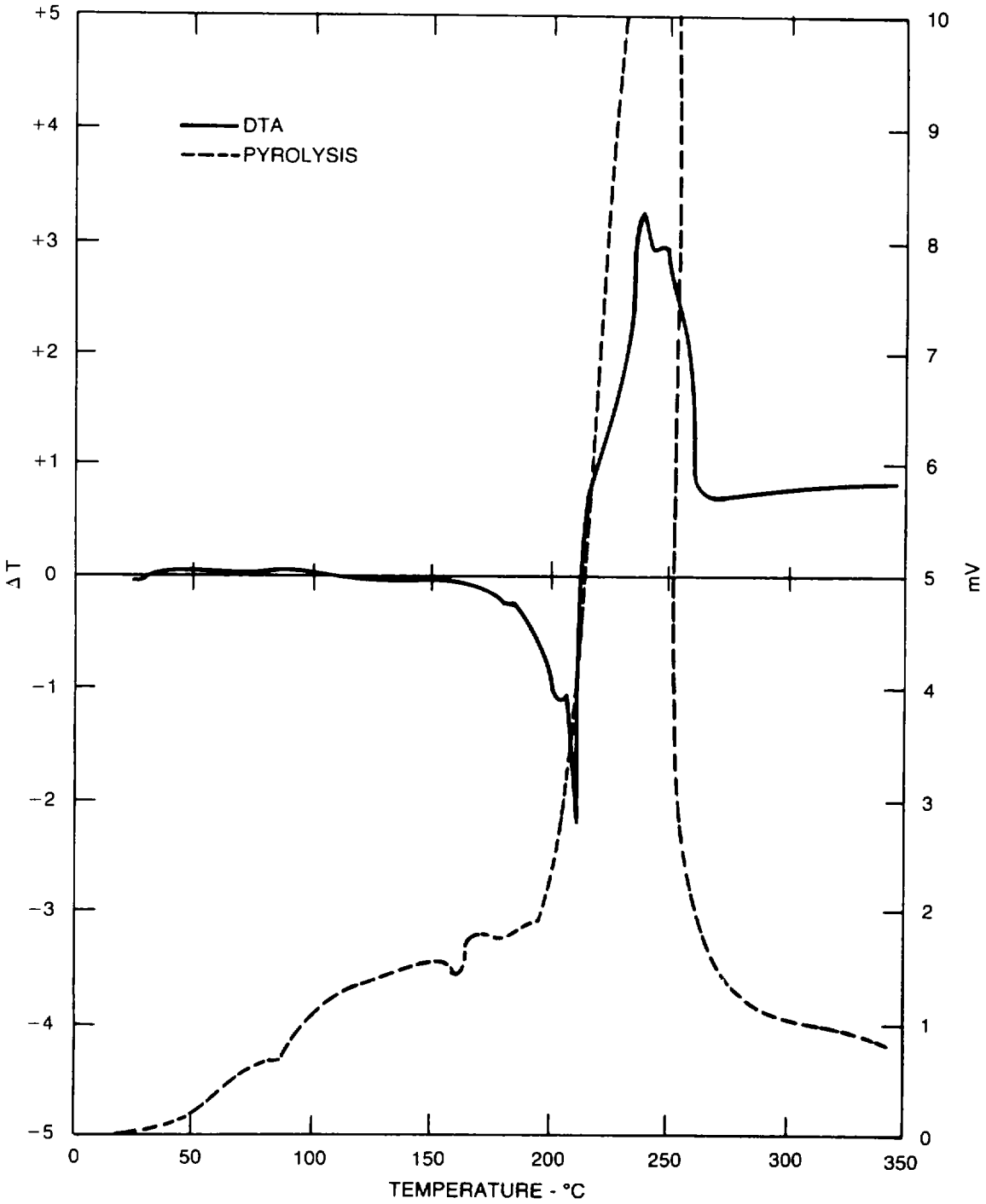


Figure 8-84. DTA curve for composition C3.

(f) In an air blast the peak pressure is 105 percent of TNT and the impulse is 109 percent of TNT.

(g) Composition C3 hardens at-29°C and has undesirable volatility and hygoscopicity characteristics, so composition C4 has been developed. The ingredients of the three classes of composition C4 are:

Class I: 61 percent RDX class A or B, type A or B
30 percent RDX class E, type A or B
9 percent polyisobutylene
Class II: 92 percent RDX class H, type A or B
9 percent polyisobutylene
Class IV: 89.9-1 percent RDX
10 +1 percent polyisobutylene
0.2+0.02 percent dye composition
which consists of:
90 percent lead chromate
10 percent lamp black

Composition C4 is a pufflike material of dirty white to light brown color. The theoretical maximum density of the mixture is 1.75 grams per cubic centimeter with a nominal density of 1.72 grams per cubic centimeter. The heat of formation is-32.9 to-33.3 calories per gram. The maximum heat of detonation with liquid water is 1.59 kilocalories per gram and with gaseous water 1.40 kilocalories per gram. Composition C4 remains plastic between -57°C and +77°C with no exudation in this temperature range. This explosive is considered a very satisfactory demolition explosive and has almost entirely replaced all the other composition C explosives.

(h) Composition C4 is manufactured by placing the water wet RDX in a stainless steel mixing kettle and adding the plastic binder. The mass is blended by tumbling the kettle until a homogeneous mixture is obtained. The resulting dough is then dried in trays by forced air at 50°C to 60°C. About 16 hours of drying are required to reduce the moisture content to below 0.25 percent.

(i) The detonation characteristics of the composition C explosives are listed in table 8-68. The detonation pressure is 257 kilobars for composition C4 with a density of 1.58 grams per cubic centimeter.

Table 8-68. Detonation Characteristics of Composition C Explosives

Test	Characteristics as a percentage of TNT			
	C	C2	C3	C4
Sand test	108	99	112	116
Plate dent test	112	111	114-118	115-130
Fragmentation test	-	-	113	-
Detonation velocity in meters per second	7,400	7,800	7,625	8,040
Trauzl test	126	-	117	-
Ballistic mortar test	125	126-143	126	130

(j) Impact tests indicate composition C4 is less sensitive than composition C3. The rifle bullet test results, with only 20 percent of the vials burning, also indicate less sensitivity. Composition C4 is unaffected in the pendulum friction test and has a five second explosion temperature of 263°C to 290°C. The minimum initiating charge required is 0.20 grams of lead azide or 0.10 grams of tetryl.

(k) Composition C4 is more stable than composition C3. The results of 100°C heat test are: 0.13 percent loss in the first 48 hours, no loss in the second 48 hours, and no explosions in 100 hours. The vacuum stability test at 100°C yields 0.20 cubic centimeters of gas in 40 hours. Composition C4 is essentially nonhygroscopic.

(5) Composition CH6.

(a) CH6 is an explosive mixture containing:

97.50+±0.50 percent RDX
1.50+0.15 percent calcium stearate
0.50+-0.10 percent graphite
0.50+0.10 percent polyisobutylene

The primary use of CH6 is in boosters and leads. When compared with tetryl, the material withstands higher temperature before cook off and has higher output yield, yet matches the sensitivity of tetryl. CH6 is pellitized at a density of 1.61 grams per cubic centimeter but the normal loading density is approximately 1.55 grams per cubic centimeter.

(b) In the sand test, CH6 crushes 61.3 grams of sand which indicates a brisance of 128 percent of TNT. The velocity of detonation is 8,223 meters per second.

(6) Ednatols.

(a) Ednatols are mixtures of haleite (ethylene dinitramine) and TNT. The most used haleite/TNT portions are 60/40, 55/45, and 50/50. Ednatols are yellowish, uniform blends with a melting point of 80°C. The eutectic temperature is about 80°C. In an extrudation test at 65°C there was no extrudate. Ednatols are considered satisfactory for bursting charges in ammunition. All of the following data in the discussion of the properties of ednatol refer to the 55/45 mixture. 55/45 Ednatol has an oxygen balance to carbon dioxide of -51 percent and to carbon monoxide of - 17 percent. The density of the cast explosive is 1.62 grams per cubic centimeter, which is four percent greater than that of cast TNT or haleite pressed under 206,850 kilopascals (30,000 pounds per square inch).

(b) Ednatol is. manufactured by heating TNT to about 105° in a steam jacketed melting kettle equipped with a stirrer. Wet haleite is added slowly with agitation to the molten TNT. After the haleite has been added, heating and stirring are continued until all the moisture has been driven off. The mixture is then cooled to about 85°C while being agitated, and loaded by pouring. Like TNT, ednatol undergoes some contraction in volume upon solidification.

(c) The sensitivity of ednatol, 95 centimeters with a two kilogram weight, is between the sensitivity of haleite and TNT. Ednatol is unaffected by either the steel or fiber shoe in the pendulum friction test. The rifle bullet impact test produces ignitions in seven percent of the trials with no detonations. The explosion temperature test value, 190°C, is the same as for haleite. This value is lower than the values for all of the other noninitiating high explosives. As might be expected, ednatol is more sensitive than TNT but less sensitive than haleite to initiation. The minimum detonating charge of mercury fulminate is 0.22 grams to 0.23 grams. In the booster sensitivity test using a 100 gram tetryl pellet, the 50 percent detonation point with acrawax B was 325 centimeters (1.28 inches).

(d) The sand test indicates ednatol is 112 percent as brisant as TNT. The plate dent test also indicates a brisance of 112 percent of TNT. The fragmentation test indicates a brisance of 118 percent of TNT, with fragment velocities of 832 kilometers per second at 2.74 meters and 741 kilometers per second at 7.77 meters. The velocity of detonation for a one inch diameter, unconfined, cast charge is 7,340 meters per second, 106 percent of TNT. As measured by the ballistic pendulum test and the Trauzl test, ednatol is 119 percent and 120 percent as powerful as TNT.

(e) In the 100°C heat test, a loss of 0.2 percent is reported in the first 48 hours and 0.1 percent in the second 48 hours with no explosions in 100 hours. In the vacuum stability test at 100°C one cubic centimeter of gas is evolved and at 120°C more than 11 cubic centimeters of gas are evolved. Dry ednatol has no effect on brass, aluminum, steels, cadmium, and nickel but causes very slight corrosion of copper, magnesium, and aluminum-magnesium alloys. Wet ednatol has no effect on stainless steel, but causes slight corrosion of aluminum and considerable corrosion of copper, brass, magnesium, magnesium-aluminum alloys, and mild steels. Ednatols are essentially nonhygroscopic when exposed to humid air.

(f) In an air blast the peak pressure is 108 percent of TNT, the impulse is 110 percent of TNT, and the energy is 108 percent of TNT. In an underwater blast, the energy is 113 percent of TNT. The shaped charge effectiveness is about 120 percent of TNT.

(g) The composition of ednatols can be determined by extracting a weighed sample with cold ether saturated with haleite and drying and weighing the residue. The weight of residue and loss in weight are calculated to percent of haleite and TNT, respectively.

(7) LX-14.

(a) LX-14 is an explosive which consists of 95.5 percent HMX and 4.5 percent estane 5702-F1. The mixture is a white solid with violet spots. LX-14 has a theoretical maximum density of 1.849 grams per cubic centimeter, a nominal density of 1.83 grams per cubic centimeter, and a melting point of greater than 270°C, with decomposition. The heat of formation is 1.50 kilocalories per mole. The calculated heats of detonation are 1.58 kilocalories per gram with liquid water and 1.43 kilocalories per gram with gaseous water. At a density of 1.835 grams per cubic centimeter the detonation velocity is 8,830 meters per second.

(b) As shown in figure 8-85, LX-14 is moderately easy to ignite in the Susan test, requiring an impact velocity of about 48 meters per second. Nosecap deformation is generally greater than 25 millimeters before ignition is observed. Reaction levels are large and somewhat erratic once the threshold velocity is exceeded. This data indicates that accidental, mechanical ignition of LX-14 has a moderately low probability of building into a violent reaction or detonation where there is little or no confinement. Figure 8-86 shows the DTA curve for LX-14.

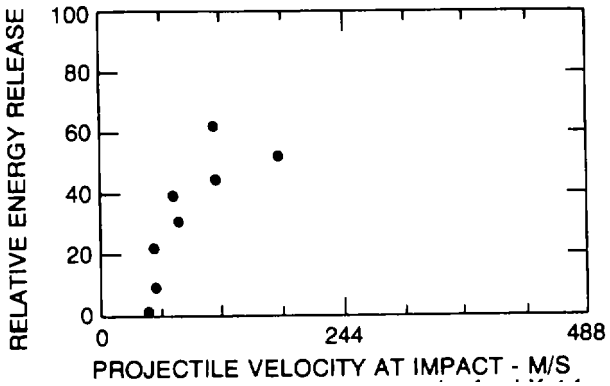


Figure 8-85. Susan test results for LX-74.

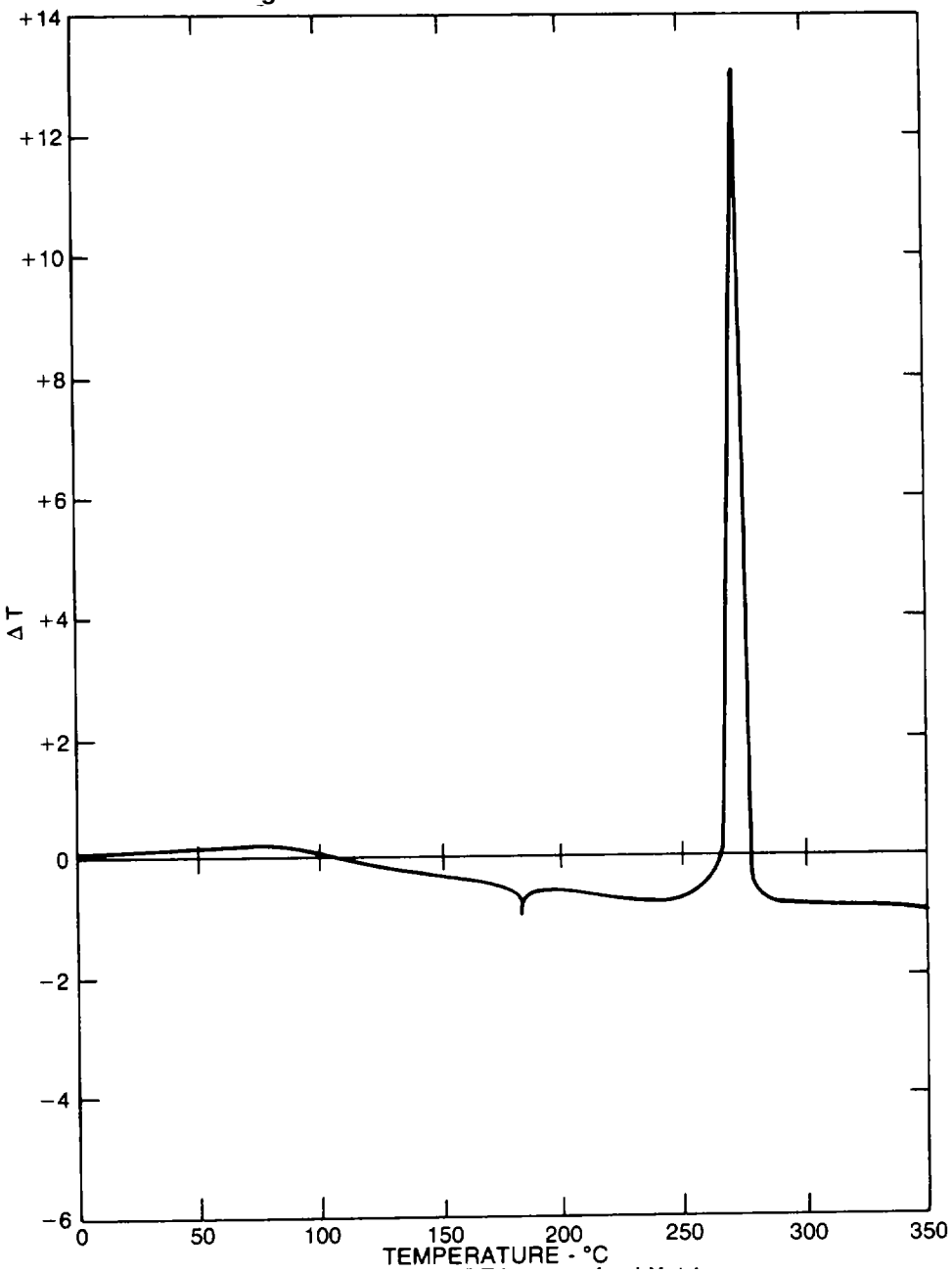


Figure 8-86. DTA curve for LX-14.

(8) Octols.

(a) Octols are mixtures of HMX and TNT. The properties of the two most commonly used octols are summarized in table 8-69.

Table 8-69. Properties of Octols

	Type I	Type Ii
Percent HMX	75 ±2.0	70±2.0
Percent TNT	25 ±2.0	30±2.0
Density in grams per cubic centimeter:		
Theoretical maximum	1.832-1.843	1.819-1.822
Open melt cast	1.800	1.790
Vacuum melt cast	1.801-1.825	1.805-1.810
Calculated heat of detonation in calories per gram:		
With liquid water	1,570	-
With gaseous water	1,430	-
Heat of combustion in calories per gram	2,676	2,722
Heat of fusion in		
kilocalories per mole	2.57	-
Specific heat in calories per gram per degree centigrade (76,9/23.1 HMX/TNT):		
at-79°C	0.200	-
-80°C < t <80°C	0.240	-
33°C < t <74°C	0.245	-
90°C < t < 150°C	0.323	-
Temperature of solid slurry		
phase change °C	79	79
Latent heat of solid to		
slurry phase change in calories per gram	5.87	7.05
Vapor pressure at 100°C in torr	0.1	-
Impact sensitivity (Picatinny Arsenal Apparatus):		
inches	17	18
Sample weight in milligrams	25	26
inches	15	19
Sample weight in milligrams	19	20
Friction pendulum:		
Steel shoe	Unaffected	Unaffected
Fiber shoe	Unaffected	Unaffected
Autoignition temperature, °C	100	108
Explosion temperature, °C:	288	289
Seconds 0.1 (no cap used)	-	-
Seconds 1	-	-
Seconds 5 (flames erratically)	350	335
Sensitivity to initiation:	0.3	0.3
(minimum detonating charge lead azide in grams)		

Table 8-69. Properties of Octols (Cont)

	Type I	Type II
Sensitivity to setback pressure in kilopascals at 71°C		
Probability of reaction:		
0.1 percent	655,025	551,600
50 percent	820,505	820,505
99.9 percent	1,027,355	1,213,520
0 percent	524,020	634,340
Pit fragmentation (105mm MI HE projectile)	Number of fragments	Number of fragments
1/2-2 grains	1,611	1,297
2-5 grains	777	665
5-10 grains	535	497
10-25 grains	719	661
25-50 grains	480	471
50-75 grains	246	247
75-150 grains	339	322
150-750 grains	293	295
750-2,500 grains	8	12
Detonation rate (no confinement-cast) in meters per second		
Charge density in grams per cubic centimeter	1.81	1.80
Charge dimensions in centimeters:		
1.27 x 1.27 x 15.24	8,643	8,377
2.54 x2.54 x 15.24	8,328	8,241
3.81 x5.08 x15.24	8,396	8,305
8,364	8,310	
Vacuum stability (milliliters of gas per five grams of sample per 40 hours)		
at 120°C	0.39, 0.65	0.37, 0.76
at 130°C	1.13	0.97
at 140°C	2.66	1.50
at 150°C	11	5.10
at 160°C	11	11
	-	
Air blast		
Weight of charge, 3,022 grams		
Distance from charge, 3,048 centimeters		
Overpressure, kilopascals	258.6	261.3
Impulse, kilopascal milliseconds	124.8	146.2
Distance from charge, 457.2 centimeters		
Overpressure kilopascals	90.3	100.6
Impulse, kilopascal milliseconds	86.2	106.9
Distance from charge, 609.6 centimeters		
Overpressure, kilopascals	48.9	46.2
Impulse, kilopascal milliseconds	62.7	77.2

(b) Octol is used as an oil well formation agent and in fragmentation and shaped charges. In fragmentation tests using a 105 millimeter M1 shell, 15 percent more fragments are produced and the average velocity of the fragments is 100 meters per second faster than with a similar shell loaded with composition B. This improvement is attributed to both the higher rate of detonation of octol and the greater density of octol which permits a greater weight of explosive in the same volume. Table 8-70 compares the performance of TNT, composition B, and octol in producing craters in a 105 millimeter shaped charge shell.

Table 8-70. Crater Volume in Mild Steel Targets

Depth of penetration in centimeters	Volume in cubic centimeters		
	TNT	Compo-sition B	Octol
4	23.8	33.1	37.0
8	36.2	49.7	57.4
12	43.2	61.4	68.9
16	49.1	69.2	78.7
20	53.0	75.1	85.0
24	56.2	79.4	89.9
28	58.6	83.0	94.0
32	61.8	86.2	98.1
36	64.3	89.3	101.8
40	-	92.3	105.3
44	-	-	110.4

(c) The gap test results for 75/25 octol are given in table 8-71.

(d) As shown in figure 8-87, 75/25 octol has both good and bad properties. The threshold velocity for reaction is about 55 meters per second which is typical of TNT bonded cast explosives. On the other hand reaction levels become moderately high at relatively low velocity. The variability of results is less than that observed with 75/25 octol. This data indicates 75/25 octol is rather difficult to ignite accidentally by mechanical means but capable of a large reaction once ignited under some conditions.

(e) In the manufacture of octols, TNT is melted in a steam jacketed kettle equipped with an agitator. The temperature of the TNT is maintained at about 100°C and water wet HMX is added slowly. Stirring is continued until the water is driven off. The kettle temperature is then reduced until a viscosity suitable for casting is obtained. The viscosity of the slurry has a strong dependence on the particle size distribution and polymorphic variety of HMX used. In order for the slurry to have an efflux time of less than 15 seconds the solid HMX must consist of the beta polymorph having particle diameters in the range of 500 to 800 microns. Even when octol is cast at a temperature of less than 90°C, there is a large amount of settling of HMX crystals while the charge is still molten. This can lead to erratic performance of the ammunition loaded. Several methods to prevent the settling are being considered. Casting temperature is kept as low as possible to prevent air entrapment in the cast. Figure 8-88 shows the DTA curve for 75/25 octol.

Table 8-71. Gap Test for 75/25 Octol

	Density	Percent voids	Sensitivity in millimeters
NSWC small scale gap test	1.829	0	4.88
	1.541	15.8	10.90
LANL small scale gap test	1.810	1.1	0.56 - 0.71
LANL large scale gap test			
regular HMX	1.822 (cast)	0.7	49.45
large crystal HMX	1.815 (cast)	1.4	47.32
vacuum cast	1.795	2.0	43.56

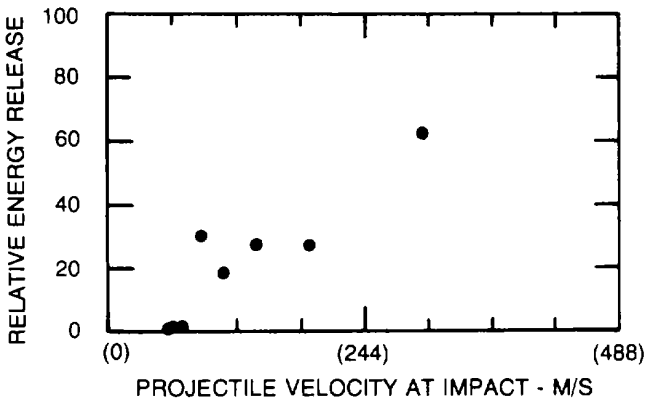


Figure 8-87. Susan test results for 75/25 octol.

(9) Pentolite.

(a) Pentolites are castable explosive mixtures containing PETN and TNT. The most commonly used blend consists of 50/50 PETN/TNT. Other blends such as 75/25, 40/60, 30/70, and 10/90 have been occasionally employed but the 50/50 blend is superior in the characteristics of sensitivity to initiation, brisance, and suitability for melt loading. 87 percent TNT and 13 percent PETN form a eutectic with a freezing point of 76.7°C. Cast 50/50 pentolite, therefore, consists of 42.2 percent PETN, and 57.8 percent of the eutectic mixture. 50/50 Pentolite has an oxygen balance to C02 of-42 percent, a heat of combustion of 1.549 kilocalories per gram, and a heat of formation of-23.4 to-24.3 kilocalories per gram. The heat of detonation with liquid water has been experimentally determined as 1.23 kilocalories per gram and the maximum calculated value is 1.53 kilocalories per gram. The heat of detonation with gaseous water has been experimentally determined as 1.16 kilocalories per gram and the maximum calculated value is 1.40 kilocalories per gram. The cast density of pentolites does not vary appreciably with blend composition. 50/50 Pentolite has a cast density of 1.63 to 1.67 grams per cubic centimeter while 10/90 pentolite has a cast density of 1.60 grams per cubic centimeter. The density of pressed pentolite is between 1.60 and 1.65 grams per cubic centimeter. Since pentolites are blends they are soluble in the same solvents as their constituent ingredients.

(b) Pentolite is manufactured by either of two methods. In the more modern, slurry method, the PETN is suspended by agitation in water heated above 80°C. TNT is then added. The temperature of the water causes the TNT to melt and coat the particles of PETN. The slurry is then cooled with rapid agitation, causing the TNT to solidify. The granules then are separated on a filter or in a centrifugal wringer and dried at a temperature below 75°C. In the coprecipitation method, the PETN and TNT are dissolved separately in acetone, the TM 91300-214 solutions are mixed and filtered, and the two explosives are precipitated simultaneously by pouring the solution into water with vigorous agitation. The precipitated solid is then separated and dried. The slurry method permits better particle size control than the coprecipitation method. Acetone is used in the slurry method for obtaining PETN of the desired particle size, but less acetone is used than in the coprecipitation method. The slurry method also takes less time per production cycle. Casting is usually accomplished at about 90°C. Constant stirring is required to keep the PETN suspended as only about 20 percent of the PETN dissolves at that temperature. Small elongated crystals are desirable for this operation to minimize settling of the PETN and prevent the production of nonuniform charges. At 90°C to 94°C PETN crystals retain their original shape characteristics since very little solution occurs. These crystals are enclosed by crystalline TNT. Added wax causes no obvious change in microstructure.

(c) Two grades of pentolite are used for military purposes. These differ only in that grade II material complies with a bulk density requirement. Grade I is used for melt loading, while grade II is used in the manufacture of pellets and the press loading of ammunition. The requirements are:

Volatile matter	Maximum, 0.5 percent	
Composition	PETN, 50±+2 percent TNT, 50±+2 percent	
Total acetone insoluble	Maximum, 0.04 percent	
Inorganic acetone insoluble	Maximum, 0.02 percent	
Grit	None	
Acidity or alkalinity	Maximum, 0.005 percent	
PETN granulation applicable to pentolite manufactured by the coprecipitation method		
Through sieve number	30	200
Percent, minimum	95	0
Percent, maximum	-	30
100°C vacuum stability test	Maximum 5 milliliters of gas	
Bulk density	Grade 11, 0.70-0.10 gram per milliliter	

(d) The Picatinny Arsenal impact apparatus and the Bureau of Mines apparatus yield conflicting results; 12 inches and 34 centimeters, respectively. The rifle bullet impact test confirms the more sensitive test result. The five second explosion temperature test result is essentially that of PETN. In the pendulum friction test pentolite is unaffected. The minimum detonating charges of lead azide and mercury fulminate required for pentolite are intermediate between those for PETN and TNT and are very close to that of tetryl. The gap test results are given in table 8-72.

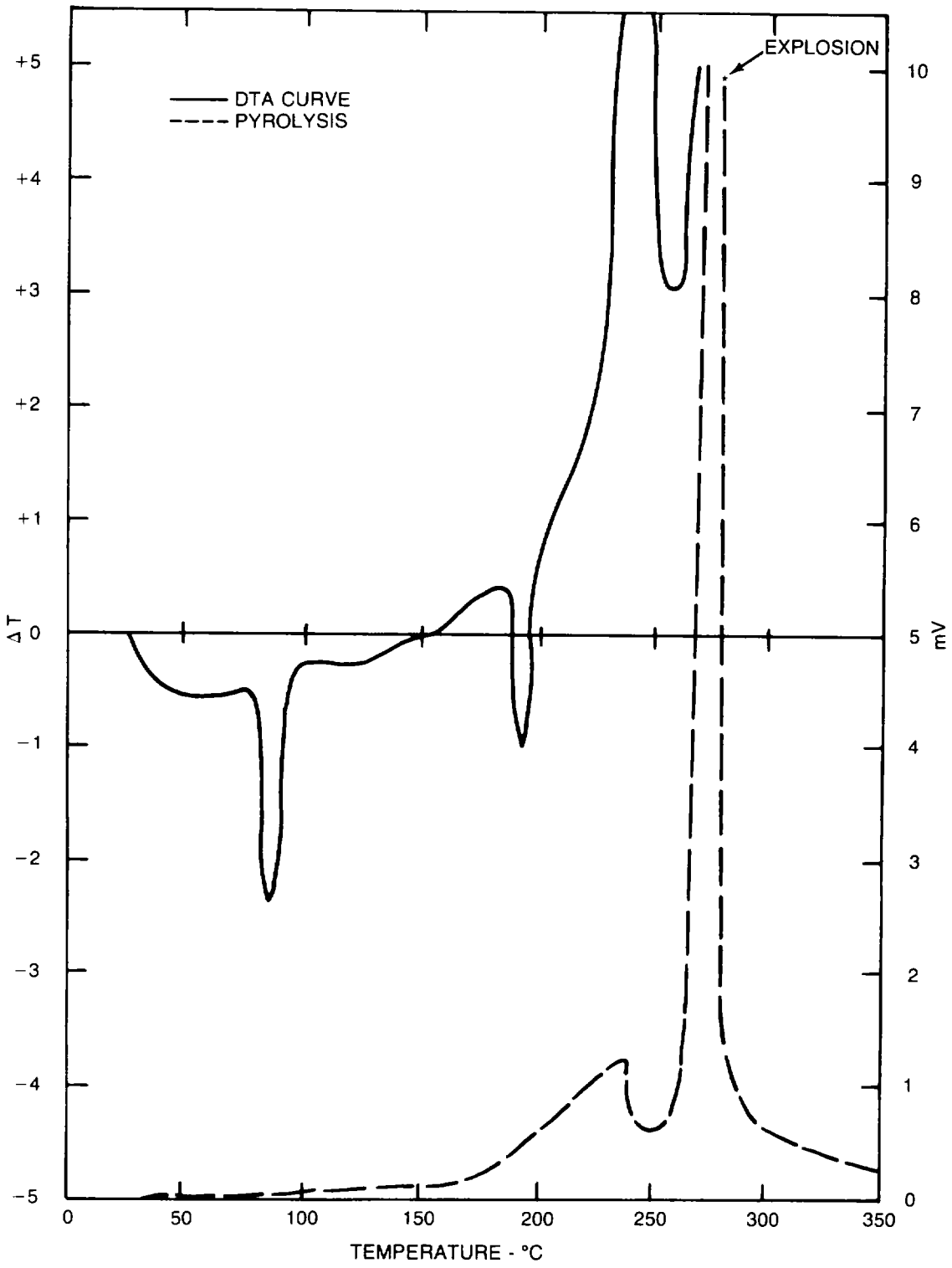


Figure 8-88. DTA curve for 75/25 octol.

Table 8-72. Gap Test Results for 50/50 Pentolite

	Density	Percent Voids	Sensitivity in millimeters
NSWC small scale gap test	1.671	2.3	10.03
	1.363	30.3	12.45
LANL small scale gap test	1.700 (cast)	0.6	0.76-0.97
	1.676 (hot pressed)	2.0	3.12
	0.75	56.1	4.80
LANL large scale gap test	1.702	0.8	64.74
	1.635	4.4	68.66

The presence of rust or grit increases the sensitivity of pentolite. A mixture of equal weights of pentolite and dry rust has an impact test value of 21 centimeters compared with 32 centimeters for the pentolite used to make the mixture.

(e) Sand test shows 50/50 pentolite to be as brisant as tetryl and 114 percent as brisant as TNT.

Fragmentation tests of shell charges, however, show pentolite to be 13 percent as brisant as TNT and plate dent tests indicate the ratio to be 126 percent. The approximate velocity of detonation as a function of packing density is given by the equation:

$$D = 5480 + 3100(\rho - I)$$

where D is in meters per second and p, the density, is in grams per cubic centimeter. This ideal velocity of detonation is applicable to charges with a diameter of one inch. The variation in detonation velocity as a function of temperature is given by the equation:

$$D - D_o = (-0.4 \times 10^{-3})(T - T_o)$$

where T is in degrees centigrade and D is in millimeters per microsecond. Do is the initial detonation velocity at temperature To, and D is the detonation velocity at temperature T. The Chapman-Jouquet detonation pressure is 232 to 255 kilobars. In deflagration to detonation transfer studies with pentolite that is heavily confined and ignited by a hot wire, a low velocity detonation regime precedes steady state detonation for 30 to 80 microseconds. Compression waves precede the burning front in this predetonation region and appear to coalesce into a shock front. The Trauzl test indicates 50/50 pentolite is 122 percent as powerful as TNT while the ballistic mortar test indicates a power of 126 percent of TNT.

(f) Vacuum stability tests indicate 50/50 pentolite is slightly less stable than PETN although storage for two years at 65°C produces no excessive acidity or great deterioration of stability. 50/50 Pentolite withstands 10 remelting operations at approximately 98°C without becoming unduly instable or unduly acid, but subsequent storage at 65°C for six months renders the sample unduly acid. Slow decomposition starts at 110°C and is followed by the main pyrolysis reactions which generate NO2 rapidly. The rate of the pyrolysis of the mixture is faster than that of either TNT or PETN. While storage at 65°C has only a limited effect on the chemical stability of pentolite, some exudation occurs for storage temperatures above 50°C. This may be due to the formation of a eutectic mixture of TNT and impurities in PETN. One of the impurities present in PETN is dipentaerythritol hexanitrate, which melts at 73.6°C and forms a eutectic mixture with TNT that freezes at only 57.9°C.

(g) Because of the somewhat lower stability and greater sensitivity of PETN as compared with RDX, the corresponding relationship of pentolite to composition B, and the tendency of pentolite to undergo some exudation above 50°C, pentolite has generally been replaced by composition B. Figure 8-89 shows the DTA curve for pentolite.

(h) The composition of pentolite is determined by extracting a weighed sample with chloroform saturated with PETN, drying the residue, and weighing. The weight of the residue and the loss in weight are calculated to percentage of PETN and TNT, respectively.

(i) Underwater blast for pentolite with a density of 1.6 grams per cubic centimeter are given by the equations:

$$\text{Peak pressure} = 2.25 \times 10^{4} (W^{1/3}/R)^{1.3} \text{ psi}$$

$$\text{Impulse} = 2.18 W^{1/3} (W^{1/3}/R)^{1.05} \text{ psi-sec}$$

$$\text{Energy} = 3.27 \times 10^{3} W^{1/3} (W^{1/3}/R)^{2.12} \text{ inch lb/inch}^2$$

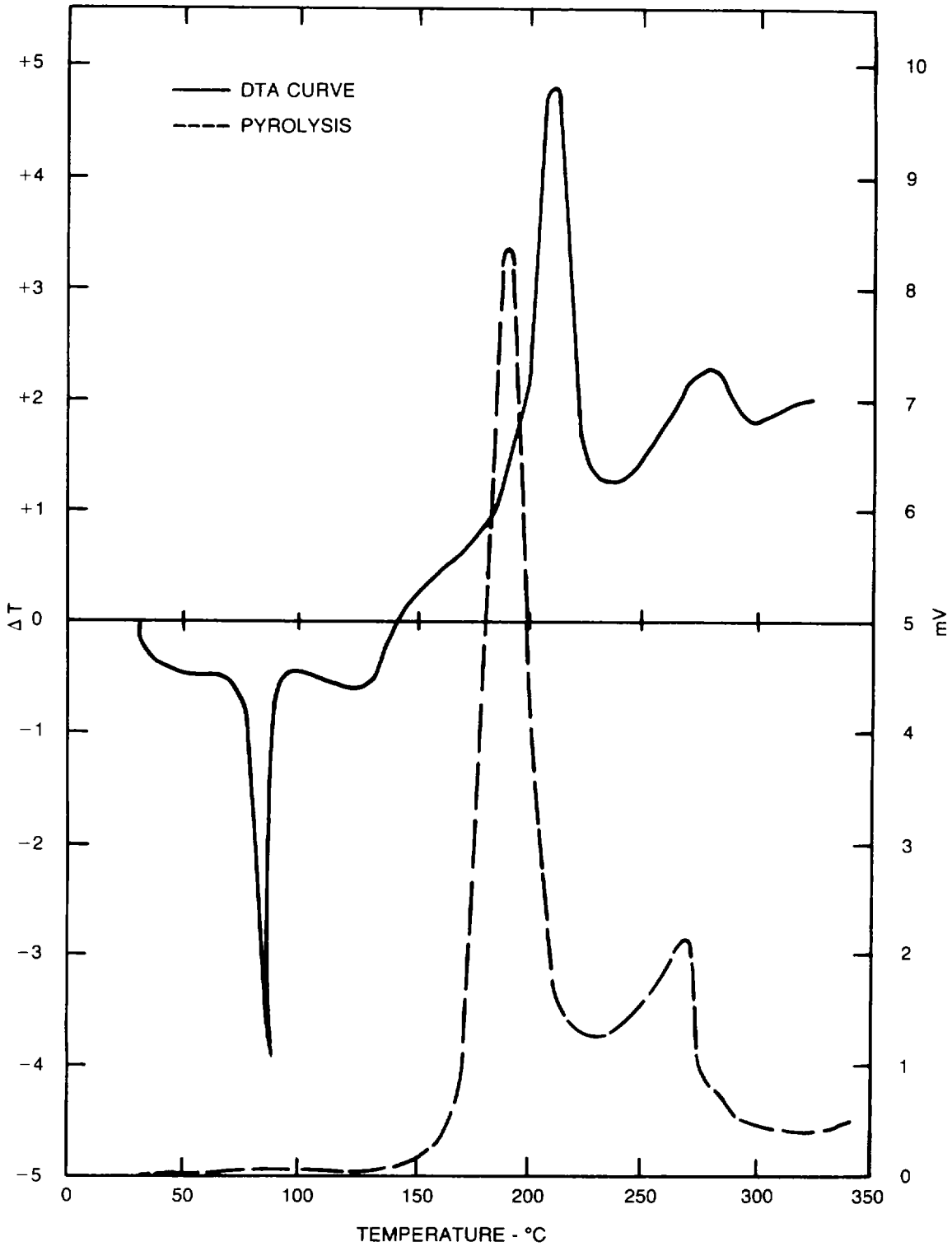


Figure 8-89. DTA curve for pentolite.

where *W* is the charge weight in pounds and *R* is the distance in feet from the center of a spherical charge.

The ratio of underwater shock energy of pentolite to the total chemical energy is 0.57 to 0.59.

(10) Picratol.

(a) Picratol is a mixture of 52 percent ammonium picrate and 48 percent TNT. Molten TNT has little or no solvent action on ammonium picrate, and consequently, cast picratol consists essentially of a physical mixture of crystals of the two explosives. The density of cast picratol is 1.61 to 1.63. This permits a weight of charge almost equal to that of ammonium picrate pressed under 68,950 to 82,740 kilopascals (10,000 to 12,000 pounds per square inch). The solubility and reactivity characteristics of picratol are essentially that of the two ingredients.

(b) Picratol is manufactured by heating TNT to above 90°C in a steam jacketed melting kettle equipped with a stirrer. The ammonium picrate is added slowly, without preheating, with continuous agitation and this is continued for a short time after all the ammonium picrate has been added. The thick slurry is allowed to cool to about 85°C before being loaded into ammunition components. Like molten TNT, picratol undergoes marked contraction in volume upon solidification. The contraction is much less than in the case of TNT.

(c) The standard small scale impact tests indicate picratol to be as sensitive to impact as TNT, rather than ammonium picrate and large scale impact tests of cast charges confirm this. Pendulum friction tests show no difference between picratol, TNT, and ammonium picrate with respect to sensitivity to friction.

When subjected to the rifle bullet impact test, picratol burns in about 40 percent of the trials but undergoes no detonation. Ammonium picrate burns in about 30 percent of the trials. The explosive temperature test value of picratol, 285°C, is less than that of ammonium picrate, 318°C, and much less than that of TNT, 475°C. Picratol is as insensitive to initiation as ammonium picrate, having a minimum detonating charge value of 0.06 gram of tetryl. The overall sensitivity of picratol, therefore, is not greater than that of TNT.

(d) 52/48 picratol is only 94 percent as brisant as TNT, as judged by the sand test, but the plate dent test indicates the two to be equally brisant, and the fragmentation of shell charges show picratol to be 102 percent as brisant as TNT. The rate of detonation of cast picratol is 101 percent that of cast TNT. Picratol and TNT are of equal power, as measured by the ballistic pendulum test, and have equal blast effects.

TM 9-1300-214 (e) The stability of picratol is very slightly less than that of either TNT or ammonium picrate as measured by vacuum stability tests at 1000, 1200, ar,d 150°C.

These test results may indicate slight reaction between the ammonium picrate and the molten TNT ingredients at the elevated temperatures of the tests. At ordinary temperatures, there is no evidence of such reaction and picratol appears to be of the same high order of stability as its ingredients.

(f) The composition of picratol can be determined by extracting a weighed sample with cold ether that has been saturated with ammonium picrate. The residue is dried and weighed and this and the loss in weight are calculated to percentage of ammonium picrate and TNT, respectively.

(11) Tetrytols.

(a) Tetrytols are light yellow to buff mixtures of TNT and tetryl. As is the case for tetryl, tetrytols are no longer used by the United States but are still being used by other nations including various NATO allies. Tetrytols resemble tetryl more closely than they resemble TNT.

They are more powerful but less sensitive than TNT.

Tetrytols can be cast into munitions, which is an advantage over press loading. Table 8-73 compares the physical characteristics of various tetrytol compositions.

The pressed density listed is for material that passed through a number 100 US standard sieve and was subjected to a pressure of 20,685 kilopascals (3,000 pounds per square inch). 70/30 Tetrytol is the most commonly used form and has a voidless density of 1.71 grams per cubic centimeter. All of the tetrytols are subject to exudation above 65°C. TNT and tetryl form a eutectic mixture that has a freezing point of 67.5°C. The solubility characteristics and chemical reactivity of the tetrytols are essentially those of the individual ingredients.

(b) Tetrytol is manufactured by heating TNT in a melting kettle equipped with an agitator until all the TNT is melted and the temperature of the liquid slightly exceeds 100°C. The proper amount of tetryl is then added with continued stirring. Part of the tetryl dissolves in the TNT. The temperature is then allowed to decrease until the mixture has thickened somewhat and is considered to be of the maximum viscosity suitable for pouring in the melt loading operation. The tetrytol is then poured into the ammunition component or a mold. As cast, tetrytol is a mixture of tetryl and the TNT-tetryl eutectic. The eutectic contains approximately 55 percent tetryl.

Table 8-73. General Characteristics of Tetrytols

Percentage composition by weight	Cast density in grams per cubic centimeter	Pressed density in grams per cubic centimeter	Molecular weight	Oxygen balance to CO_2	Melting point °C	Former United States usage
80/20 Tetrytol	1.51	-	274	-52	68	not used
75/25 Tetrytol	1.59	1.34	270	-54	68	bursting charge, demolition explosive
70/30 Tetrytol	1.60	1.36	266	55	68	bursting charge, burster charge in chemical shells
65/35 Tetrytol	1.60	1.38	264	-56	68	burster charge in land mines

(c) There is no difference in the impact sensitivity of 65/35, 70/30, or 75/25 tetrytol. All are less sensitive than tetryl and more sensitive than TNT. All tetrytols are unaffected by the steel and fiber shoes in the pendulum friction test. The rifle bullet impact test, in which a 30 caliber bullet is fired into the open end of a pipe confined charge, yields the following results:

	Unaffected percentage	Partially affected percentage
80/20 Tetrytol	80	20
75/25 Tetrytol	70	30
70/30 Tetrytol	45	55
65/35 Tetrytol	90	10

In a wax gap test 75/25 tetrytol is somewhat more sensitive than composition B, but appreciably less sensitive than pentolite. The following shows the minimum priming charge required for the tetrytols.

	Grams lead azide	Grams mercury fulminate
80/20 Tetrytol	0.17	0.22
75/25 Tetrytol	0.19	0.23
70/30 Tetrytol	0.22	0.23
65/35 Tetrytol	0.23	0.23

For a priming charge of diazodinitrophenol (DDNP) the minimum charge required is 0.19 grams for pressed 75/25 tetrytol at a density of 1.4 grams per cubic centimeter and 0.31 grams for cast 75/25 tetrytol.

(d) In the plate dent test the brisance of 75/25 tetrytol at densities of 1.66 grams per cubic centimeter and 1.62 grams per cubic centimeter is 118 percent and 114 percent of TNT, respectively. 70/30 Tetrytol at 1.60 grams per cubic centimeter has a brisance of 117 percent of TNT. The sand test indicates 70/30 tetrytol is 97.5 percent and 111 percent as brisant as tetryl and TNT, respectively. The following detonation velocities were measured in one inch diameter charges without confinement. For cast 75/25 tetrytol with a density range of 1.55 to 1.60 grams per cubic centimeter and an average of 1.57 grams per cubic centimeter, the measured detonation velocities ranged from 7,290 to 7,410 meters per second with an average of 7,350 meters per second. For cast 65/35 tetrytol with a density range of 1.56 to 1.61 grams per cubic centimeter and an average of 1.58 grams per cubic centimeter, the measured detonation velocities ranged from 7,310 meters per second to 7,370 meters per second with an average of 7,340 meters per second. The ballistic mortar test indicates 75/25 and 70/30 tetrytols are 122 percent and 120 percent of TNT, respectively.

(e) 70/30 Tetrytol is slightly less stable than tetryl at 100°C and higher temperatures, as shown by vacuum stability tests. However, at 65°C and lower temperatures, samples have been stored for two years with no change in stability, acid content, sensitivity, or brisance. Although tetryl undergoes partial decomposition on melting, the melting of tetrytol does not have the same effect. Tetrytol that has been melted and solidified 12 times shows no change in freezing point, sensitivity to impact, or 100°C vacuum stability test value although the temperature was each time raised to 107°C and maintained at that value for half an hour prior to solidification by cooling. Storage at 65°C causes some separation of an oily extrudate and distortion of blocks of tetrytol, so the maximum storage temperature is less than 65°C. This low storage temperature has caused the United States to discontinue the use of tetrytol. Tetrytol

is incompatible with 3M adhesives EC8708 and EC1099. Dry tetrytol is compatible with copper, brass, aluminum, magnesium, stainless steel, mild steel coated with acid proof paint, and mild steel plated with copper, cadmium, zinc or nickel. Magnesium-aluminum alloys are slightly affected by dry tetrytol. Wet tetrytol is compatible with stainless steel and mild steel coated with acid proof black paint. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel, and mild steel plated with cadmium, copper, zinc, or nickel are slightly affected by wet tetrytol.

(f) The shaped charge effectiveness of 70/30 tetrytol at a density of 1.64 grams per cubic centimeter, as gauged in a constant volume test, is appreciably lower than composition B, octol, and composition A, when all are at roughly equivalent packing densities. 60/40 Tetrytol is as efficient a shaped charge filler as 50/50 pentolite and somewhat better than TNT. Both 75/25 and 65/35 tetrytols are approximately 1.2 to 1.25 times more effective shaped charge fillers than TNT.

(g) Determination of the composition of a sample of tetrytol can be made by treating a weighed sample with sufficient boiling carbon tetrachloride to dissolve the TNT present, cooling to 0°C, evaporating a weighed portion of the solution to dryness, and correcting for the amount of tetryl dissolved by the carbon tetrachloride at 0°C.

(12) Tritonal.

(a) Tritonal is a silvery solid that contains:

TNT	80 percent
Flaked aluminum	20 percent

Metallic aluminum is insoluble in TNT so tritonal begins to melt at the melting point of TNT. Tritonal has a heat of combustion of 4,315 calories per gram per degree centigrade at constant pressure and a thermal conductivity of 0.0011 calories per gram per degree centigrade at 0°C. These values are 120 percent and 200 percent of those for TNT. At 20°C the calculated specific heat is 0.305 calorie per gram per degree centigrade. Like TNT, tritonal undergoes considerable expansion on melting and contraction on freezing. The solubility characteristics of tritonal are essentially those of TNT. Tritonal is used as a filler in bombs and shells. The density of the cast material is 1.73 grams per cubic centimeter.

(b) The chemical reactivity of tritonal is that of TNT and aluminum. In addition in the presence of moisture, the TNT and aluminum undergo slight reaction with the evolution of gas. This is not of practical importance because of the very slight hygroscopicity of TNT and the fact that any moisture present is driven off by heat during the manufacture of tritonal.

(c) 80/20 Tritonal is manufactured from TNT and grained aluminum. The TNT and aluminum are run slowly through separate chutes into a steam heated melting kettle equipped with a stirrer which is kept in motion while the ingredients are being added. Heating and mixing are continued until all the TNT is melted, the temperature is greater than 81°C, and the fluidity of the mixture is considered satisfactory. The tritonal is then loaded by pouring into bombs, using at least the same precautions and techniques used in the melt loading of TNT.

(d) Although the pendulum friction test shows no measurable difference in sensitivity between tritonal and TNT, impact tests indicate tritonal to be somewhat more sensitive to impact that TNT and less so than tetryl. The rifle bullet impact test value for tritonal is more similar to that of tetryl than that of TNT. The explosion temperature test value of tritonal, 470°C, is almost identical with that of TNT. Liquid tritonal at 90°C is slightly more sensitive than the solid, as judged by rifle bullet impact tests. As indicated by the sand test, the minimum detonating charge of lead azide, 0.30 gram, is slightly greater than that required for TNT. Nonstandard initiation sensitivity tests with diazodinitrophenol as the initiator show tritonal and TNT to be of essentially the same sensitivity to initiation.

(e) The sand test indicates 80/20 tritonal is 108 to 114 percent as brisant as TNT. The plate dent test and the fragmentation test indicate a brisance of 93 percent and 91 percent of TNT respectively. The rate of detonation of cast tritonal is approximately 97 percent that of cast TNT. The heat of explosion of tritonal is 59 percent greater than that of TNT, but tritonal is only 124 percent as powerful as TNT, as measured by the ballistic pendulum test. The Trauzl test indicates tritonal is 153 percent as powerful as TNT.

(f) As tritonal has the same 150°C vacuum stability test value as TNT, aluminum and TNT do not react at that or lower temperatures. Tritonal, therefore, has the same stability as TNT, if free from moisture. Deterioration in the presence of moisture is not serious, probably because the formation of a layer of oxide on the surface of the particles of aluminum prevents or retards further reaction. Tritonal, like TNT, can undergo exudation if stored at elevated temperatures, but this tendency is less than that of TNT because of the presence of 20 percent by weight of metallic particles that tend to hold oily exudate by surface tension. This prevents the oily exudate from coalescing and exuding.

(g) When tested for blast effect, tritonal has a peak pressure of 113 percent of TNT and an impulse value of 118 percent of TNT.

(h) The composition of a sample of tritonal is determined by extracting a weighed sample with benzene, drying the residue, and weighing the sample. The loss in weight represents TNT and the weight of residue represents aluminum. Each is calculated to a percentage basis.

b. Ternary Mixtures.

(1) Amatex 20.

(a) Amatex 20 consists of:

RDX	40 percent
TNT	40 percent
Ammonium nitrate	20 percent

The mixture has a nominal density of 1.61 grams per cubic centimeter and is used as a filler in ammunition items.

(b) Amatex 20 is slightly less sensitive than TNT, with impact test results of 15 to 18 inches on the Picatinny Arsenal apparatus. In the rifle bullet impact test of 100 trials, six detonated low order, three burned, and the rest are unaffected. The relative gap test value is 105 percent of TNT. The five second explosion temperature is 240°C.

(c) The detonation velocity at 1.61 grams per cubic centimeter is 6,944 meters per second, although values of 6,830 meters per second at a density of 1.68 grams per cubic centimeter have been reported. A detonation pressure of 240 kilobars has been reported for a charge with a density of 1.68 grams per cubic centimeter. The ballistic mortar test indicates amatex 20 is 110 percent as powerful as TNT. Vacuum stability tests indicate amatex 20 is a highly stable explosive.

(2) Ammonal.

(a) Ammonals are mixtures containing, as principle ingredients, ammonium nitrate and powdered aluminum incorporated with high explosives such as TNT, DNT, and RDX. Powdered carbon was also used in earlier ammonals. In the ammonals that do not contain carbon, the mixture of ammonium nitrate and high explosive detonates developing a very high temperature which causes volatilization of the aluminum powder. Secondary reactions which follow involve the oxidation of the vaporized aluminum, either by the air, if oxygen is present, or by the products formed on detonation of TNT and ammonium nitrate according to the following equations:

$$3CO_2 + 2Al \longrightarrow Al_2O_3 + 3CO$$
$$3H_2O + 2Al \longrightarrow Al_2O_3 + 3H_2$$

Both these reactions are highly exothermic and develop much additional heat which causes greater expansion of the gases and consequently greater blast effect.

Many different combinations of ingredients have been used, both militarily and commercially. The most recent United States military ammonal consists of 22 percent ammonium nitrate, 67 percent TNT, and 11 percent flaked aluminum. The oxygen balance of the compound is 55 percent to CO2 and 22 percent to CO. The major use of this composition is as a projectile filler.

(b) As in the case of ammonium nitrate in amotols, the ammonium nitrate of ammonals might be hydrolyzed in the presence of moisture with the formation of ammonia but, due to the presence of aluminum, the amount of ammonia will be much greater. This amount might be as much as three times greater with ammonals than with 80/20 amatol. The ammonia reacts with TNT to form a complex addition compound which ignites at 67°C. In addition, the reaction between aluminum and moisture produces hydrogen, which is highly inflammable in oxygen or compounds containing oxygen.

(c) The general effect of incorporating aluminum in ammonium nitrate/TNT mixtures is as follows:

1. Increase in sensitivity to impact, friction, and rifle bullet impact.

2. Increase of temperatures of detonation from about 1,700°C to about 3,914°C to 4,000°C.

3. A 20 percent increase in power.

4. An increase in some cases of the total volume of gas evolved on detonation.

5. A decrease in velocity of detonation and brisance.

(d) Ammonals are manufactured by a method similar to that used for the preparation of amatols. The calculated amount of TNT is placed in a kettle that is equipped with an agitator and steam jacket.

The temperature of the kettle is raised to between 85°C and 100°C. The calculated amount of ammonium nitrate, which was previously heated to the same temperature as the contents of the kettle, is then added. Finally aluminum powder is added and the mass cooled while continuing the agitation. If the ammonal mixture contains less than 40 percent TNT, press loading is necessary. For compositions with more than 40 percent TNT, the mixture can be cast loaded.

(e) In general, ammonals are fairly insensitive and stable mixtures but are hygroscopic due to the presence of ammonium nitrate. In the presence of moisture, ammonals react with the same metals as amatols: copper, bronze, lead, and copper plated steel.

(3) High Blast Explosives.

(a) Three compositions of high blast explosives are used as shown in table 8-74.

Table 8-74. High Blast Explosives

	HBX-1	HBX-3	H-6
RDX (including nitrocellulose, calcium chloride, and calcium silicate	40.4 ±3.0%	31.3 ±3.00%	45.1 ±3.0%
TNT	37.8 ±3.0%	29.0 ±3.0%	29.2 ±3.0%
Aluminum	17.1 ±3.0%o	34.8 ±3.0%	21.0 ±3.0%
Wax and lecithin	4.7 ± 1.0%	4.9 ±1.0%o	4.7 ± 1.0%
Oxygen balance			
to CO_2	-68	-75	-
to CO	-35	-49	-
Density in grams per cubic centimeter:			
Theoretical maximum	1.76	1.882	-
Nominal	1.69- 1.74	1.81 - 1.86	1.75
Heat of combustion in calories per gram	3,882	4,495	-
Heat of detonation in calories per gram:			
with liquid water	1,840	2,110	-
with gaseous water	1,800	2,110	-
Impact sensitivity as a percentage of TNT	75	70	-
Rifle bullet impact sensitivity as a percentage of TNT	75	80	-
Gap test sensitivity as a percentage of TNT	80	90	-
Fragmentation test in 90-mm, HE, M71 shell, number of fragments (TNT-703)	910	476	-
Brisance by sand test as a percent of TNT	102	93.5	
Detonation velocity in meters per second	7,222	6,920	7,190
at density (in grams per cubic centimeter)	1.75	1.86	1.71
Detonation pressure in kilobar			23.7
Ballistic mortar:	133% TNT	111% TNT	-
% TNT in air (shock)	121	116	-
%. TNT in air (impulse)	121	125	-
Heat test at 100'C:			
% Loss in 1st 48 hrs	0.058	0.70	-
% Loss in 2nd 48 hrs	0	0	-
Explosions in 100 hrs	None	None	-
Hygroscopicity, % loss (in 7 days at 30° and 95% relative humidity)	2.98	2.01	-

Table 8-74. High Blast Explosives (Cont)

	HBX-1	HBX-3	H-6
Blast effects:			
% TNT under water (shock)	111	101	-
% TNT under water (bubble)	145	191	-

(b) HBX explosives are prepared by melting TNT in a steam jacketed kettle equipped with a mechanical stirrer. Water wet RDX is added slowly with stirring and heating until all the water is evaporated. Powdered aluminum is added and the mixture is stirred until uniform. D2 wax and calcium chloride are then added and the mixture is cooled to a temperature suitable for casting. HBX can also be prepared by adding the calculated amount of molten TNT to molten composition B to obtain the desired proportion of RDX and TNT. Then the appropriate weights of other ingredients are added to complete the composition. D2 wax, also referred to as composition D2, consists of 84 percent paraffin wax, 14 percent nitrocellulose, and 2 percent lecithin. Figure 8-90 shows the DTA curve for H6.

(4) HMX, TNT, and aluminum mixture 3 (HTA-3).

(a) There are two types of HTA-3 as shown in table 8-75:

Table 8-75. HTA-3 Composition

	Type I	Type II
Percent HMX	49	49
Percent TNT	29	28.65
Percent aluminum	22	22
Percent calcium silicate	-	0.35

The mixture has an oxygen balance to C02 of -21 percent and a specific gravity of 1.90 when cast. The heat of combustion is 3,687 calories per gram and the heat of explosion is 1,190 calories per gram. The specific heat is 0.245 calories per gram per degree centigrade.

(b) To manufacture HTA-3, TNT is heated to about 1 00°C in a steam jacketed kettle equipped with an agitator. Water wet HMX is added slowly to the molten TNT. Stirring and heating are continued until all the water is evaporated. Aluminum powder is then added and the mixture is cooled with continued stirring. When a satisfactory viscosity is obtained the HTA-3 is cast.

(c) The impact test result on the Picatinny Arsenal apparatus is 17 inches for a 25 milligram sample. In the pendulum friction test HTA-3 is unaffected by either the steel or fiber shoe. The rifle bullet impact test indicates a relatively high sensitivity. 90 percent of the trials explode and the other 10 percent burn. HTA-3 requires a minimum detonating charge of 0.30 grams of lead azide. The five second explosion temperature is about 370°C.

(d) In the sand test, HTA-3 crushes 61.3 grams of sand indicating a brisance of 128 percent of TNT for an unconfined cast charge 2.54 centimeters in diameter. The detonation rate is 7,866 meters per second. In the 120°C vacuum stability test, 0.37 cubic centimeters of gas are evolved in 40 hours from a one gram sample.

(5) Minol-2.

(a) Minols are mixtures of TNT, ammonium nitrate, and aluminum. Minol-2 which is the type currently used, has the following composition:

TNT	40 $\pm$3 percent
Ammonium nitrate	40 $\pm$3 percent
Aluminum	20 $\pm$3 percent

The explosive is a gray solid with a cast density of 1.62 to 1.74 grams per cubic centimeter. The heat of formation is 46.33 kilocalories per mole. The heat of detonation is 2.01 kilocalories per gram with liquid water and 1.86 kilocalories per gram with gaseous water. The heat of combustion is 3,160 calories per gram. At a density of 1.74 grams per cubic centimeter and a temperature of -5°C, minol-2 has a specific heat of 0.30 calories per gram per degree centigrade. Minols are used in four types of ordnance: underwater depth bombs, block buster bombs, concrete fragmentation bombs, and general purpose bombs. In underwater ordnance the confinement effects of the water somewhat offset the effects of the relatively low detonation velocity. In block buster bombs a sustained and powerful impulse is more destructive than a high peak pressure. In concrete fragmentation bombs, the high impulse will impart a satisfactory velocity to the fragments but will not pulverize the concrete.

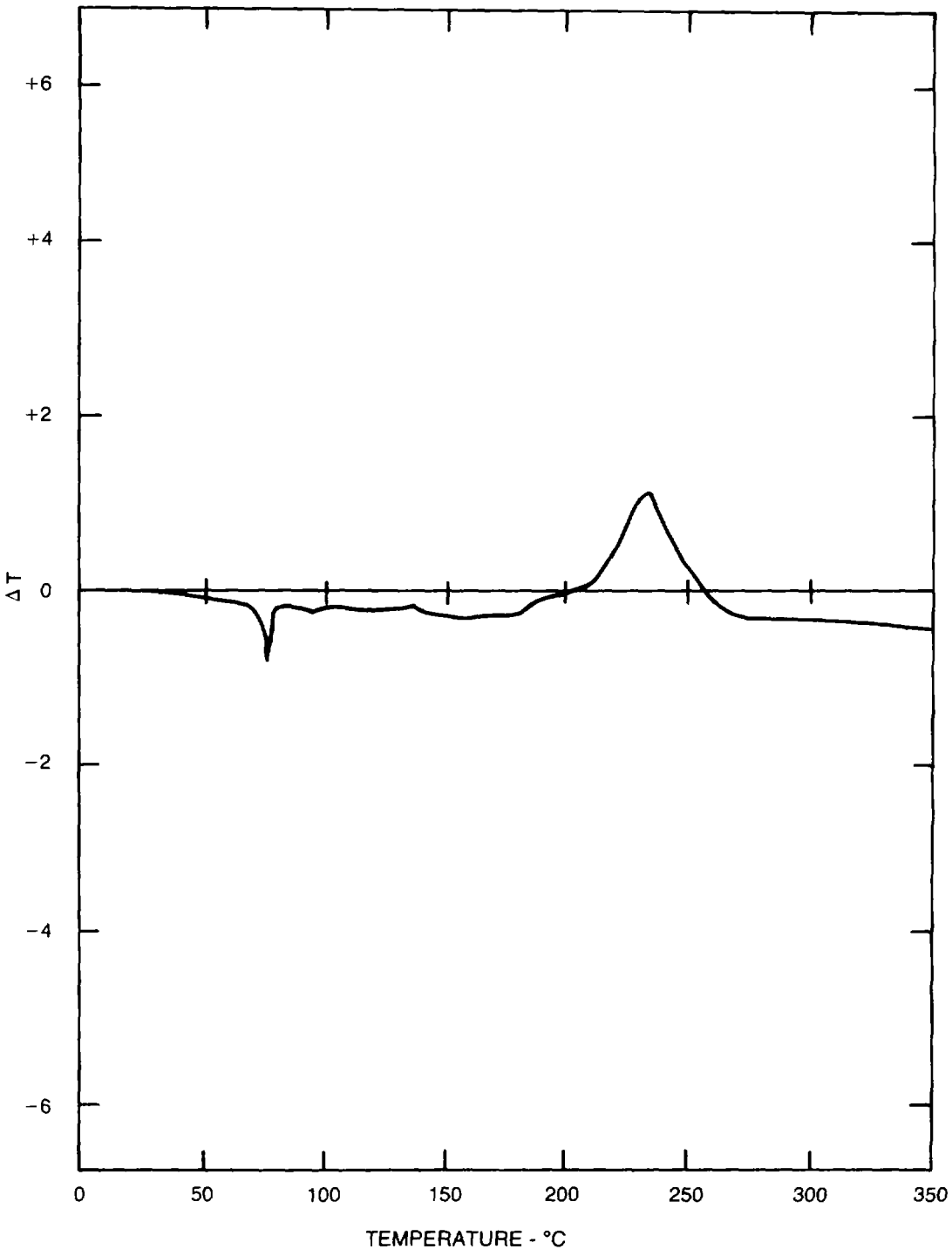


Figure 8-90. DTA curve for H6.

(b) Minols are manufactured by adding appropriate quantities of dry ammonium nitrate and aluminum powder to molten TNT at about 90°C under agitation. Originally the aluminum was in the form of a fine powder, however, such a fine degree of subdivision is not necessary. The larger aluminum particles do not cause any loss of performance and have a smaller surface area per unit volume and so reduce the reactivity of the aluminum in the mixture and increase the stability.

(c) The impact sensitivity, as measured by the Picatinny Arsenal apparatus with a 17 milligram sample, is 13 inches. Using the Bureau of Mines apparatus, with a 20 milligram sample, the drop height is 35 centimeters. In the rifle bullet test 62 percent of the trials were affected. The five second explosion temperature is 224°C to 260°C. The flammability index is 100. The 50 percent level in the booster sensitivity test is 3.71 centimeters using a 100 gram tetryl pellet and minol-2 with a density of 1.74 grams per cubic centimeter. The relative gap test value is 120 percent of TNT.

(d) In the sand test minol-2 crushes 40.5 grams of sand indicating a brisance of 86 percent of TNT. The plate dent test indicates a brisance of 66 percent of TNT. In the fragmentation test the fragment velocity is about the same as for TNT. The detonation velocity at a density of 1.62 to 1.68 grams per cubic centimeter is 5,900 meters per second and at 1.77 grams per cubic centimeter is 6,200 meters per second. The ballistic pendulum test and the Trauzl test indicate that minol-2 is 143 percent and 165 percent as powerful as TNT, respectively.

(e) In the 100°C vacuum stability test minol-2 does not evolve any gas in 48 hours, but in the 120°C test a 5.0 gram sample evolves 2.1 cubic centimeters of gas in 40 hours. When stored in munitions, minols tend to spew or ooze. The cause of this problem has not been determined at the present time. Minol-2 expands more but extrudes less than TNT or tritonal under similar temperature cycling conditions. Dry minol-2 is stable and unreactive when cycled between ambient temperature and 100°C. If the minol-2 is prepared with dry ammonium nitrate there is no phase change under 50°C. However, when ammonium nitrate that is not thoroughly dry is used, the minol-2 will exhibit a reversible phase transition beginning at 32°C, producing volume changes of about 3.8 percent. These volume changes could cause microcrystalline cracks and pores which could reduce detonation velocity and mechanical strength.

(6) Torpex.

(a) Torpex is a silvery white solid when cast. The composition of torpex is 41.6 percent RDX, 39.7 percent TNT, 18.0 percent aluminum powder, and 0.7 percent wax. The density of cast torpex is 1.82 grams per cubic centimeter. At 15°C the specific heat is 0.24 calories per gram per degree centigrade. When the explosive undergoes solidification, there is a decrease in volume of six percent. Torpex is nonhygroscopic where exposed to air of 90 percent relative humidity at 30°C. When heated, torpex undergoes partial melting near the melting point of TNT. The partially liquid explosive has viscosity values of 4.5 and 2.3 poises at 83°C and 95°C, respectively. This is approximately the viscosity of glycerin at room temperature.

(b) Torpex is manufactured by melting TNT in a steam jacketed kettle equipped with a stirrer and heating the molten TNT to approximately 100°C. RDX that is slightly wetted with water is added slowly and mixing and heating are continued until all water has been driven off. Grained aluminum is added and the mixture is stirred until uniformity is obtained. The mixture is then cooled, with continued stirring, until the viscosity is suitable for pouring. The aluminum tends to settle out of the torpex in large castings if the liquid is allowed to set too long. To prevent this, a portion of the casting is poured and allowed to cool to the point of crusting over before another layer of torpex is poured. Torpex of slightly different composition can be manufactured by melting 12.5 parts of TNT, adding 69.5 parts of composition B and, after heating and stirring, adding 18 parts of aluminum. This illustrates the fact that torpex is essentially aluminized 50/50 octol.

(c) Torpex is considerably more sensitive to impact than composition B and undergoes partial or complete explosions in all trials in the rifle bullet impact test. Torpex is more impact sensitive at higher temperatures as is indicated by the following data.

Temperature in degrees centigrade	Impact sensitivity
25	15
32	7
104	8

The five second explosion temperature test value, 260°C, is the same as that of RDX. Cast torpex is much more sensitive to initiation than cast TNT and pressed torpex is as sensitive as RDX to initiation by mercury fulminate.

(d) Sand tests indicate torpex to be 98 to 99 percent as brisant as RDX and 122 percent as brisant as TNT. As judged by plate dent test values, cast torpex is 120 percent as brisant as TNT. Fragmentation tests of shell charges indicate torpex to be 126 percent as brisant as TNT and, therefore, inferior to composition B in this respect. The rate of detonation of cast torpex is 110 percent that of TNT. The heats of combustion and explosion are 3,740 calories per gram and 1,800 calories per gram, respectively. Trauzl tests for the heat of explosion indicate torpex to be 161 to 162 percent as powerful as TNT, but the ballistic pendulum test gives torpex a superiority of only 34 percent. Torpex has a great blast effect. The following blast comparisons are relative to TNT as 100:

	Air	Air, confined	Underwater
Peak pressure	122	-	116
Impulse	125	116	127
Energy	146	-	153

(e) Vacuum stability tests show torpex to be of the same order of stability as composition B. Storage at 75°C for one month or 65°C for 13 months has no effect on the stability of torpex. In the 100°C heat test there is no weight loss in the first 48 hours, 0.10 percent weight loss in the second 48 hours, and there is no explosion in 100 hours. Torpex, therefore, has high stability. However, moisture reacts with the ingredients in torpex causing the evolution of gas which can cause rupture of the ammunition component or cause an increase in the sensitivity of torpex to shock. For this reason all moisture must be removed during manufacture.

(f) The composition of torpex can be determined by extracting a weighed sample with cold benzene or toluene that has been saturated with RDX. The residue is dried and weighed and the loss in weight is calculated to percentage of TNT. The dried residue is extracted with hot acetone, dried, and weighed. The loss in weight is calculated to percentage of RDX. The weight of the final residue is calculated to percentage of aluminum.

(g) The shaped charge efficiency of torpex relative to TNT as 100 is:

	Glass cones	Steel cones
Hole volume	150	145
Hole depth	127	131

c. Quanternary Mixtures.

(1) Depth bomb explosive (DBX) is the only explosive covered under quanternary mixtures. DBX consists of:

TNT	40 percent
RDX	21 percent
Ammonium nitrate	21 percent
Aluminum	18 percent

DBX was developed to replace the more sensitive torpex. As the name indicates, the primary use of DBX is in depth charges. The mixture is a gray solid that is slightly hygroscopic and, except for the aluminum, is soluble in acetone. The density of the cast material is from 1.61 grams per cubic centimeter to 1.76 grams per cubic centimeter. The method of manufacture is similar to that of torpex except that casting is done at 90°C to 95°C.

(2) The impact sensitivity of DBX is slightly less than that of TNT; 10 inches on the Picatinny Arsenal apparatus versus 14 inches for TNT. In the rifle bullet impact test about 49 percent of the samples exploded from the impact of a 30 caliber bullet at a distance of 2,743 meters (90 feet). The five second explosion test value is 200°C. The minimum detonating charge is 0.20 grams of lead azide and 0.10 grams of tetryl.

(3) The sand test results indicate a brisance of 112 percent of TNT. The detonation velocity is 6,630 meters per second for a density of 1.65 grams per cubic centimeter and 6,800 meters per second at a density of 1.76 grams per cubic centimeter. By the ballistic mortar test the power of PBX is 146 percent of TNT. For the 100°C vacuum stability test, 0.6 cubic centimeters of gas are evolved in 40 hours. The energy of the air blast is 138 percent of TNT and the energy of the water blast is 143 percent of TNT.

d. Plastic Bonded Explosives (PBX).

(1) PBX is a term applied to a variety of explosive mixtures which have high mechanical strength, good explosive properties, excellent chemical stability, relative insensitivity to handling and shock, and high thermal input sensitivity. The detonation velocity of PBX's is usually above 7,800 meters per second, the average autoignition temperature is above 250°C and the shock sensitivity is usually 10 to 40 percent above that required for detonating the basic explosive. PBX's contain a large percentage of basic explosives such as RDX, HMX, HNS, or PETN in intimate mixture with a polymeric binder such as polyester, polyurethane, nylon, polystyrene, various types of rubbers, nitrocellulose, or teflon. In some instances a plasticizer such as dioctylphthalate (DOP), DPA, or butyldinitrophenylamine (BDNPA) is included in the ingredients as well as a fuel such as powdered aluminum or iron.

(2) Much of the advantage stemming from the use of PBX lies in the simplicity of the technique of end item manufacture. About half of the developed PBX composites are used to directly cast end items. For this procedure no elaborate melting equipment or controlled cooling cycles are required. All operations may be conducted at ambient temperatures or, in some instances, can even be carried out in the field. However, where extraordinary mechanical strength is required or where complicated shapes are desired, a pressing or injection technique is applied using a molding powder or slurry of the PBX. The final PBX product not only exhibits excellent technical properties but also has the economical advantages of low processing costs and the ready availability of all constituents from commercial sources.

In currently evolved compositions, recycling and disposal present no special difficulties because thermally degradable binders are used. Ideally, the binders undergo controlled thermal degradation so that the material can be easily removed from explosive casings for the purpose of efficient recycling of the base explosive or low pollution disposal of the entire item.

(3) Several manufacturing procedures are currently used to produce PBX's. One of these techniques is that of casting. This procedure, at first glance, merely involves combining a dried explosive, such as HMX, with binder constituents and curing initiators in a mixing vessel, blending to desired homogeneity, then casting into a given warhead or other ordnance item. Unfortunately, there are hazards associated with the drying of large quantities of explosives such as HMX or RDX. Hence, a desensitizing procedure must be added for production-scale operations. This procedure involves coating the water wet HMX or RDX with the alkyd or polyester portion of the binder. The resulting lacquer is added slowly to an aqueous slurry of the HMX or RDX. Agitation at 250 revolutions per minute in the presence of water causes the resin to precipitate onto the surface of the HMX or RDX, producing an insensitive powder which may be safely dried, handled, shipped, and stored until ready for use in the final PBX composition. The precoated explosive is then combined in a mixing kettle with sufficient copolymer to constitute the final binder composition. At this point an accelerator such as cobalt naphthenate is added. The mixture is then stirred until homogeneous, at first under ambient pressure and finally in a partial vacuum to remove entrapped air. A curing agent such as methyl ethyl ketone peroxide is then added. After another short mixing period, the explosive composition is poured into the desired mold. Vacuum casting has not been found necessary to obtain good density provided that the mold design is not too intricate or the height-to-diameters ratio not too great. Another method of casting is called injection molding. This method is used to produce intricate shaped or small diameter castings. The PBX usually employed with this technique has a high solid content of explosive such as PETN, which provides for steady state detonation in small cross-sectional channels or tubes. This method was developed by the Navy to provide explosive logic links of less than .25 centimeters in diameter. Figure 8-91 illustrates the injection molding process. The technique of injection molding involves movement of explosive material at room temperature into a cavity or tubing from a reservoir. This is accomplished by applying about 82,740 kilopascals (12,000 pounds per square inch) to the piston. This forces the explosive into the cavity or tube. When the accepting device is full, pressure on the piston is relaxed and flow stops. The device is then removed and set aside to allow the explosive to polymerize into an elastic, rubber-like solid. A second manufacturing technique produces a molding powder which is pressed into the desired end item shape under pressure in excess of 206,850 kilopascals (30,000 pounds per square inch). A slurry method can be used to prepare RDX type PBX's. In this method 42.5 grams of polystyrene and eight cubic centimeters of dioctylphthalate were dissolved in 200 cubic centimeters of toluene in a lacquer dissolver. Steam is introduced into the jacket until the temperature is 65°C. The lacquer is agitated constantly then added to a granulator. This lacquer contains a four to one ratio of plastic-plasticizer to toluene. The granulator which is agitated at 400 revolutions per minute, contains 450 grams of RDX and 4,500 grams of water which has been heated to 75°C. The lacquer solution is poured into the granulator followed by a solution of gelatin in water. Mixing is continued for five minutes to insure the RDX is well dispersed. Granulation takes place at this point. Steam is introduced into the jacket again to distill the solvent until the temperature reaches 98°C. Cooling water is then run into the jacket to cool the batch to 40°C. The coated material from the granulator is collected on a Buchner funnel and dried in a tray at 70°C for 24 hours.

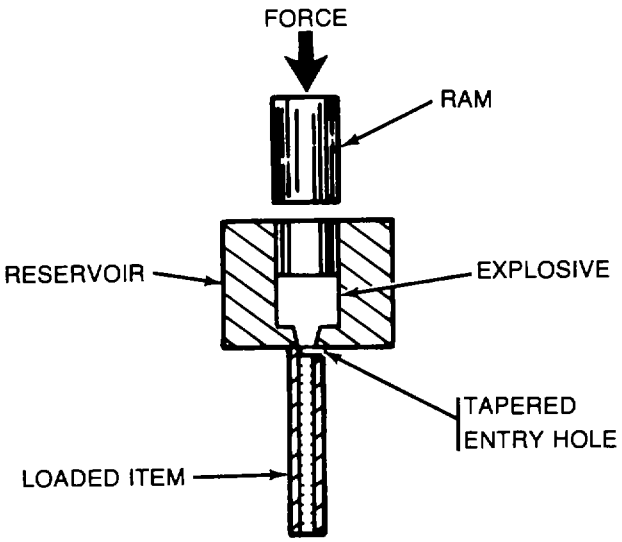


Figure 8-91. Injection loading operation.

(4) Table 8-76 lists the composition of the PBX's currently produced and used for military purposes.

Table 8-76. PBX Compositions

Designation	Composition
PBXN-4	94 percent DATB 6 percent nylon
PBXN-5	95 percent HMX 5 percent copolymer of vinylidene fluoride and hexafluoropropylene
PBXN-6	95 percent RDX 5 percent copolymer of vinylidene fluoride and hexafluoropropylene
PBXN-201	83 percent RDX 12 percent copolymer of vinylidene fluoride and hexafluoropropylene 5 percent polytetrafluoroethylene (teflon)
PBX-0280	95 percent RDX 5 polyethylene binder
PBX Type I	90 percent RDX 8.5 percent polystyrene 1.5 percent Dioctylphthalate (DOP)
PBXC-116	86 percent RDX 14 percent elastomeric binder
PBXAF-108	82 percent RDX 16 percent plasticizer 2 percent binder

PBXN-5 is also known as LX-10-0. This compound has blue-green spots on a white background. The theoretical maximum density is 1.896 grams per cubic centimeter with a nominal density of 1.86 to 1.87 grams per cubic centimeter. The melting point, with decomposition, is greater than 250°C, and the heat of formation is -31.4 calories per gram. The heat of detonation with liquid water is 1.55 kilocalories per gram and the heat of detonation with gaseous water is 1.42 kilocalories per gram. In the LANL small scale gap test a hot pressed charge of density 1.872 grams per cubic centimeter and a pressed charge of density 1.857 grams per cubic centimeter had 50 percent points of 2.25 .25 millimeters and 2.29 millimeters, respectively. Figure 8-92 shows the DTA curve for PBXN-5.

e. Industrial Explosives.

(1) Dynamites.

(a) Military operations frequently necessitate excavation, demolition, and cratering operations for which the standard high explosives are unsuited. Recourse is made to commercial and special compositions. Commercial blasting explosives, with the exception of black powder, are referred to as dynamites although in some cases they contain no nitroglycerin.

(b) Nobel gave the name dynamite to mixtures of nitroglycerin and kieselguhr, the strength of the dynamite being indicated by the percentage of nitroglycerin in the mixture. Kieselguhr is a chemically inert but porous material. Nitroglycerin absorbed by kieselguhr is much safer to handle than the unabsorbed material. Later, even stronger dynamites were made by substituting sodium nitrate and a combustible absorbent, such as wood pulp, for the kieselguhr. The resulting composition was called an active dope dynamite. Subsequently, the replacement of part of the nitroglycerin and sodium nitrate by ammonium nitrate brought into existence the less costly ammonia dynamites that are notable for their great heaving rather than shattering effects. The replacement of nitroglycerin in dynamite by nitrostarch resulted in the development of a class of dynamites free from some of the objectionable characteristics of nitroglycerin dynamites. While the active dope and ammonia dynamites are hygroscopic and desensitized by water, necessitating a moisture-proof wrapper, a waterproof composition termed blasting gelatin is obtained by colloiding nitrocellulose with nitroglycerin. When mixtures are made of 88 to 92 percent of nitroglycerin and 8 to 12 percent of nitrocellulose having a nitrogen content of about 12 percent, a relatively tough material is formed. Blasting gelatins are particularly adapted to deep-water blasting. By including some nitrocellulose in the compositions of active dope dynamites, the so-called gelatin dynamites were formulated.

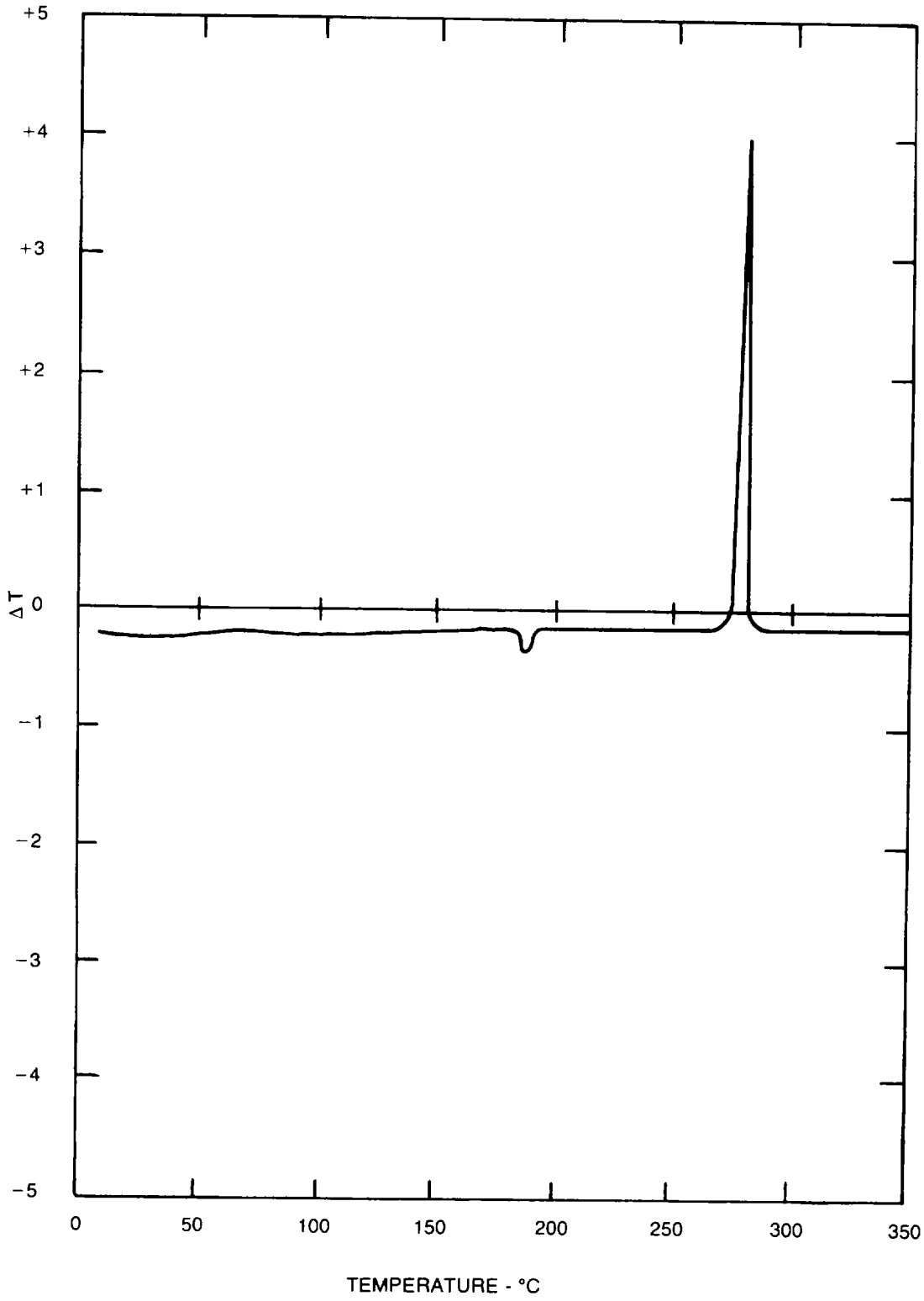


Figure 8-92. DTA curve for PBXN-5.

These possess greater density and water resistance than straight active dope dynamites and so are more suitable for use under wet conditions.

(c) The cost of glycerin and the tendency of nitroglycerin to freeze at some atmospheric temperatures prompted the partial replacement of nitroglycerin by antifreeze materials such as nitrated diglycerin, sugars, and glycols. Antacid materials such as calcium carbonate or zinc oxide have been added to most dynamite compositions to neutralize any acidity developed during storage. The inclusion of special purpose ingredients such as sulfur, ferrosilicon, alum, nitrotoluenes, sodium chloride, copper sulfate, etc and the substitution of starch, ground peanut hulls, vegetable ivory, etc, for wood pulp have further increased the complexity of dynamite compositions. Usually, they are formulated so as to have certain rate of detonation and heaving force values that render them suitable for various types of blasting operations. At the same time care must be taken that the compositions are oxygen balanced when the paraffined paper wrapper is taken into consideration. Compositions overbalanced with respect to oxygen produce nitrogen oxides on detonation while underbalanced compositions produce some carbon monoxide instead of carbon dioxide. While many of the commercial dynamites are given strength designations on a percentage basis, this no longer means that they contain that percentage of nitroglycerin or have the same characteristics as a mixture of kieselguhr and nitroglycerin containing that percentage of nitroglycerin. Representative compositions and characteristics of the various types of dynamite are given in table 8-77.

Table 8-77. Compositions[1] and Characteristics of Dynamites

Strength of dynamite, percent	20	30	40	50	60	100
Straight dynamites:						
Nitroglycerin	20.2	29.0	39.0	49.0	56.8	-
Sodium nitrate	59.3	53.3	45.5	34.4	22.6	-
Carbonaceous fuel	15.4	13.7	13.8	14.6	18.2	-
Sulfur	2.9	2.0	-	-	-	-
Antacid	1.3	1.0	0.8	1.1	1.2	-
Moisture	0.9	1.0	0.9	1.2		
Rate of detonation, m/sec	3,600	4,300	4,800	5,150	5,900	-
Ballistic pendulum, percent TNT	83	90	94.5	102.5	114	-
Ammonia dynamites:						
Nitroglycerin	12.0	12.6	16.5	16.7	22.5	-
Sodium nitrate	57.3	46.2	37.5	25.1	15.2	-
Ammonium nitrate	11.8	25.1	31.4	43.1	50.3	-
Carbonaceous fuel	10.2	8.8	9.2	10.0	8.6	-
Sulfur	6.7	5.4	3.6	3.4	1.6	-
Antacid	1.2	1.1	1.1	0.8	1.1	-
Moisture	0.8	0.8	0.7	0.9	0.7	-
Rate of detonation, m/sec	2,700	-	3,300	3,900	4,600	-
Ballistic pendulum, percent TNT	81	-	91	99	109	-
Gelatin dynamites:						
Nitroglycerin	20.2	25.4	32.0	40.1	49.6	91.0[2]
Sodium nitrate	60.3	56.4	51.8	45.6	38.9	-
Nitrocellulose	0.4	0.5	0.7	0.8	1.2	7.9
Carbonaceous fuel	8.5	9.4	11.2	10.0	8.3	-
Sulfur	8.2	6.1	2.2	1.3	-	-
Antacid	1.5	1.2	1.2	1.2	1.1	0.9
Moisture	0.9	1.0	0.9	1.0	0.9	0.2
Rate of detonation, m/sec	4,000	4,600	5,150	5,600	6,200	7,400
Ballistic pendulum, percent TNT	70 - 74	79	84.5 - 86	90.5 - 93	99 - 101	143

Table 8-76. Compositions' and Characteristics of Dynamites (Cont)

Strength of dynamite, percent	20	30	40	50	60	100
Ammonia gelatin dynamites:						
Nitroglycerin	-	22.9	26.2	29.9	35.3	-
Sodium nitrate	-	54.9	49.6	32.0	33.5	-
Ammonium nitrate	-	4.2	8.0	13.0	20.1	-
Nitrocellulose	-	0.3	0.4	0.4	0.7	-
Carbonaceous fuel	-	8.3	8.0	8.0	7.9	-
Sulfur	-	7.2	5.6	3.4	-	-
Antacid	-	0.7	0.8	0.7	0.8	-
Moisture-	-	1.5	1.4	1.6	1.7	-
Rate of detonation, m/sec	-	4,400	4,900	5,300	5,700	-
Ballistic pendulum, percent of TNT	-	83	88	92	97.5	-

[1]Percent by weight
[2]Blasting gelatin

(d) In addition to military dynamite (h below), dynamites of the types described may be used for military operations and are procured as commercial items. A composition having great heaving force and relatively low rate of detonation is preferable for blasting soft rock or earth, while a gelatin dynamite of low heaving force and high rate of detonation is used for hard tough rock.

(e) A special demolition explosive standardized shortly before World War II is based on nitrostarch instead of nitroglycerin. The explosive is pressed into 1/4-pound pellets which are covered with paper and one pound packages of the pellets are wrapped in paper with markings indicating the location of holes for blasting caps in the pellets. The composition used is as follows:

	Percent
Nitrostarch	34.5 ±2.5
Barium nitrate	43.5 ±1.5
TNT	15.0 ±2.0
Aluminum	3.0 ± 1.0
Graphite	2.0 ± 1.0
Coal dust	1.5 ±0.5
Paraffin	0.6 ±0.6
Dicyandiamide	1.0 ±0.5
Moisture	0.75 ±0.75

The barium nitrate is coated with the paraffin before the ingredients are mixed together and pressed into pellets. The composition must not undergo ignition or explosion when heated at 100°C for 48 hours and must have a density of 1.75+0.10 when pressed.

(f) Nitrostarch demolition explosive is sensitive with respect to crumbling or breaking action. No explosions occur in the pendulum friction test but explosions do occur in the rifle bullet impact test. The initiation sensitivity is slightly greater than that of TNT. The sand test indicates a brisance of 90 percent of TNT and the ballistic pendulum test indicates a power of 96 percent of TNT. The explosive is hygroscopic to the extent of 2.1 percent when exposed to air of 90 percent relative humidity at 30°C. Long term storage tests indicate a satisfactory stability. Some volatilization, rather than decomposition, occurs in the 100°C heat test in 96 hours. A weight loss of one percent with no signs of deterioration is reported in the 75°C international test.

(g) During World War II, a cratering explosive with the following composition was used.

	Percent
Ammonium nitrate	86.6
Dinitrotoluene	7.6
Ferrosilicon	5.7
Red dye	0.1

This inexpensive and easily manufactured explosive is very insensitive to shock and initiation, has a low rate of detonation but high heaving force value, and is very stable. As it is somewhat hygroscopic in spite of the moistureproofing action of the dinitrotoluene, the explosive is packed in hermetically sealed containers.

(h) Military dynamite M1, M2, and M3 is a medium velocity (6,096 meters per second) blasting explosive in three cartridge sizes. Military dynamite M1, M2, and M3 has been standardized for use in military construction, quarrying, and service demolition work. The explosive composition is packaged in standard dynamite cartridge waxed-paper wrappers. The models differ only in the cartridge size. Cartridges are 1 1/4 inches in diameter by 8 inches long for the M1, 1 1/2 inches in diameter by 8 inches long for the M2, and 1 1/2 inches in diameter by 12 inches long for the M3. The composition used is: Percent

RDX	75 ±1.0
TNT	15±0.5
Grade SAE No. 10 engine oil plus polyisobutylene	5 ±0.5
Cornstarch	5 ±0.5

Desensitized RDX, which is coated with engine oil before mixing with the other ingredients, and grained TNT are used in the manufacture of the dynamite. Military dynamite M1, M2, and M3 is equivalent in strength to 60 percent commercial dynamite. The military dynamite is safer to transport, store, and handle than 60 percent straight nitroglycerine commercial dynamite and is relatively insensitive to friction, drop impact, and rifle bullet impact. The composition remains plastic at 57°C after 24 hours. Military dynamites are odorless, free from nitroglycerin toxicity, nonhygroscopic, and chemically stable when exposed to 80 percent relative humidity at 71°C for one month. No freezing occurs in cold storage or exudation in hot storage. Turning of shipping containers during storage is not necessary.

(2) Ammonium nitrate fuel oil explosives (ANFO).

(a) When ammonium nitrate is mixed with approximately 5.6 percent of a combustible material such as fuel oil, the heat liberated on detonation is increased by almost three-fold. The reaction proceeds according to the equation:

$3NH_4NO_3+(CH_2)n \rightarrow$
$3N_2+7H_2O+CO_2+102.5$ kilocalories per gram

(b) Extremely insensitive to initiation, ANFO requires a high explosive booster containing 50/50 pentolite, composition B, or other similar high explosive. Sensitivity does vary somewhat with oil content. The maximum sensitivity is at about two to four percent, with a substantial reduction for greater concentrations of oil. Sensitivity is decreased by the presence of water, but decreasing the particle size or density of the ammonium nitrate prills increases sensitivity.

(c) The energy produced upon detonation is comparable to the energy produced by some of the less powerful military explosives, however, the detonation velocity is only about 4,300 meters per second in large diameter charges. With six percent oil, the detonation velocity is at maximum, but maximum energy is obtained with 5.5 percent oil. Increased charge diameter, up to about 13 centimeters, and confinement causes an increase in the velocity of detonation.

(3) Water gel and slurry explosives.

(a) Along with ANFO explosives, the water gel and slurry explosives have virtually replaced dynamite in mining operations. Water gel and slurry explosives have a higher energy content than ANFO, smaller critical diameter, and can be used in wet conditions. The gel explosives consist of ammonium nitrate with or without other oxidizing agents, explosive or nonexplosive sensitizers, fuels, and gelatin forming compounds in an aqueous medium. Slurry explosives contain the same ingredients with additional compounds that bond the solid particles and prevent water from defusing in and out of the slurry. The explosive sensitizers are such compounds as pentolite, TNT, methylamine nitrate, smokeless powder, and nitrostarch. Nonexplosive sensitizers can be finely granulated aluminum, gas bubbles in suspension, gas contained in small glass spheres, and porous solids. The fuels include coal dust, urea, sulfur, and various types of hydrocarbons. The gelatin forming compounds include guar gums, carboxymethyl cellulose, resins, and synthetic thickeners. The viscosity of the mix can be altered by the addition of cross linking agents like sodium tetraborate and potassium dichromate. Glycerol, methanol, and diethylene glycol may be added as antifreezes.

(b) The detonation characteristics of the water and slurry explosives vary considerably with the composition of the slurry. Detonation velocities vary from 4,300 to 6,050 meters per second and detonation pressures vary from 60 to 104 kilobar.

CHAPTER 9
UNITED STATES PROPELLANTS

9-1. Introduction. Selection of a propellant for an application is made on the basis of the requirements of that specific application. In general, guns are designed to meet specified performance standards and withstand a specific pressure in the barrel. With a knowledge of the properties of the constituents normally used for propellants, the propellant designer creates a formulation to satisfy the performance standards and limitations of the gun. When ignited, the propellant produces large quantities of hot, gaseous products. Complete combustion or deflagration of the propellant occurs in milliseconds in guns and the pressure produced accelerates the projectile down the barrel. Table 9-1 shows the approximate distribution of the energy content of the propellant.

Table 9-1. Distribution of Propellant Energy

Energy absorbed	Percent of total
Motion of projectile	32.0
Frictional work	2.0
Translation of gases	3.0
Heat loss to gun and projectile	20.0
Sensible and latent heat loss in gases	42.0
Rotation of projectile and recoiling parts	1.0

9-2. Chemical Composition of Propellants. Properties of the principal energetic ingredients of common gun propellants (nitrocellulose, nitroglycerin, and nitroguanidine) are discussed in Chapter 8. The composition and selected properties of various gun propellants are shown in table 9-2. The formulations arise from needs to maintain the flame temperature at certain levels, and from a desire to achieve the maximum energy content within that flame temperature limitation. Low flame temperatures, low levels of carbon monoxide, and hydrogen in the muzzle reduce the tendency of a gun to exhibit secondary flash. The main reason for seeking low flame temperatures is to reduce barrel erosion. In certain propellant systems, the need for flash reduction impacts on the flame temperature limit permitted. Usually, potassium salts are sufficiently effective in eliminating secondary flash. Also to be considered are the cost of ingredients and the physical properties of the final propellant.

Table 9-2. Composition and Properties of Propellants

	M1	M2	M5	M6	M8	M10	M31	M30	IMR	M18
Nitrocellulose (NC), %	85.00	77.45	81.95	87.00	52.15	98.00	20.00	28.00	100.00	80.00
%/o Nitrogen in NC %	13.15	13.25	13.25	13.15	13.25	13.15	12.60	12.60	13.15	13.15
Nitroglycerin,%	-	19.50	15.00	-	43.00	-	19.00	22.50	-	10.00
Barium nitrate, %	-	1.40	1.40	-	-	-	-	-	-	-
Potassium nitrate, %	-	0.75	0.75	-	1.25	-	-	-	-	-
Potassium sulfate, %	-	-	-	-	-	1.00[a]	-	-	1.00[a]	-
Lead carbonate, %	-	-	-	-	-	-	-	-	-	-
Nitroguanidine, %	-	-	-	-	-	-	54.70	47.70	-	-
Dinitrotoluene, %	10.00	-	-	10.00	-	-	-	-	8.00[b]	-
Dibutylphthalate, %	5.00	-	-	3.00	-	-	4.50	-	-	9.00
Diethylphthalate, %	-	-	-	-	3.00	-	-	-	-	
Diphenylamine, %	1.00[a]	-	-	1.00[a]	-	1.00	-	-	0.70	1.00
Ethyl centralite, %	-	0.60	0.60	-	0.60	-	1.50	1.50	-	-
Graphite, %	-	0.30	0.30	-	-	0.-10[b]	-	0.10[b]	-	-
Cryolite, %	-	-	-	-	-	-	0.30	0.30	-	-

Table 9-2. Composition and Properties of Propellants (Cont)

	M1	M2	M5	M6	M8	M10	M31	M30	IMR	M18
Ethyl alcohol (residual), %	0.75	2.30	2.30	0.90	0.40	1.50	0.30	0.30	1.50	0.50
Water (residual), %	0.50	0.70	0.70	0.50	0	0.50	0	0	1.00	0
Isochoric flame temp T_v, K	2,417	3,319	3,245	2,570	3,695	3,000	2,599	3,040	2,835	2,577
Force, 1-lb/lbxl 0-3, F	305	360	355	317	382	339	334	364	331	319
Unoxidized carbon, %	8.6	0	0	6.8	0	4	8.7	3.2	2.7	6.8
Combustibles, %	65.3	47.2	47.4	62.4	37.2	54.5	49.8	41.0	59.2	66.6
Heat of explosion, cal/g	700	1,080	1,047	758	1,244	936	807	974	868	772
Gas volume, moles/g	0.04533	0.03900	0.03935	0.04432	0.03711	0.04068	0.04620	0.04308	0.04191	0.04457
Ratio of specific heat	1.2593	1.2238	1.2238	1.2543	1.2148	1.2342	1.2527	1.2385	1.2413	1.2523
Covolume, in. 3/lb	30.57	27.91	27.52	29.92	26.63	27.76	30.87	29.26	28.91	30.24
Density, g/cm3	1.57	1.65	1.65	1.58	1.62	1.67	1.64	1.66	1.62	1.62

[a]Added.
[b]Glaze added.
[C]Ball propellant.

a. The single-base propellants shown in table 9-2 are M1, M6, M10, and IMR. Nitrocellulose is the principal energetic material. These are low cost propellants that have a low flame temperature and low energy content. To reduce the flame temperature and barrel erosion, recent formulations of the IMR propellants do not use dinitrotoluene. Ethylene dimethacrylate and methyl centralite are among the replacement materials which produce much lower flame temperatures. IMR is considered a single-base propellant even though the formulation contains a small amount of nitroglycerin.

b. The double-base gun propellants shown in table 9-2 are M2, M5, M8 and M18. In these formulations the nitrocellulose is gelatinized by nitroglycerin. The presence of an active gelatinizer makes double-base propellants more energetic than single-base propellants. The ballistic potential is increased correspondingly. The flame temperature and resulting barrel erosion is also increased. Other aliphatic nitrate esters are also used to gelatinize the nitrocellulose. DEGN is the most widely used gelatinizer but DEGN has the undesirable property of being more volatile than nitroglycerin and so, makes the propellants less stable.

c. The triple-base gun propellants contain nitroguanidine as additional energizer which increases the energy content of the formulation without raising the flame temperature. This reduces gun barrel erosion with no sacrifice in performance. In addition, the triple-base propellants have a substantially reduced concentration of combustibles such as hydrogen and carbon monoxide in the product gas. This reduces the flash from the gun barrel.

d. Composite propellants, used in solid fuel rockets, contain a polymer binder, a fuel, and an oxidizer.

9-3. Thermochemistry. Thermochemical properties are prime considerations in formulating a propellant for a specific application. The thermochemical properties include the flame temperature of the gases produced by the propellant under certain standard conditions, their average molecular weight, and covolume. The commonly used equation of state used with the combustion products of gun propellants (for gun applications) is:

$$P(V - b) = nRT$$

where P is the pressure, V is the volume, b is the covolume, n is the number of moles of the gas per unit mass, R is the universal gas constant, and T is the temperature. The ideal gas equation of state is obtained in the case where b equals zero. The covolume is a correction factor to take into account the extremely high pressures, 137,900 to 482,650 kilopascals (20,000 to 70,000 pounds per square inch), that exist in a gun barrel. Physically, the covolume is defined as the volume actually occupied by the gas molecules. Laboratories dealing with propellants have a variety of methods available, including computer programs, that are used routinely to estimate the thermochemical properties of propellants from basic chemical data. The simplest of these is the Hirschfelder-Sherman calculation in which the adiabatic, isochoric flame temperature Tv, heat of explosion Q, moles of gas per gram n, impetus (force)

F =nRTv, ratio of specific heats, and covolume are calculated. An equilibrium computer program called the BLAKE code, formulated on the basis of a virial coefficient equation of state, has been devised for gun use. The usual input required for equilibrium propellant performance calculations consists of the chemical composition, the heat of formation (Hf at 2980K), and the elemental formula of each ingredient. Several extensive compilations of heat of formation data are available.. Several techniques are available for estimating the heat of formation of compounds by addition of bond energies and/or group contribution where experimental data are lacking. A computer program has been developed for estimation of chemical thermodynamic data called "Chetah" (chemical, thermodynamic, and hazard appraisal). The estimated values obtained by these methods are usually for compounds in the ideal gaseous state. Therefore, the heat of vaporization and, sometimes, the heat of fusion must be taken into account to obtain the heat of formation of the compound in its normal state at 2980K. Experience indicates that the results of propellant performance calculations are not extremely sensitive to errors in the heat of formation of the ingredients. Recently, methods have been developed for calculating certain transport properties (for example, the thermal conductivity and viscosity) of the combustion product gases under specific conditions of temperature and pressure.

9-4. Physical Properties. Gun propellants must function reliably over a large ambient temperature range (for example, 54° to +74°C) and they must retain their performance characteristics during many years of storage. The propellant grains must retain their integrity in the face of a severe blast from the ignition system. This quality must be demonstrated particularly at low temperatures where the propellants tend to be brittle. The propellant grains must not soften excessively at high temperature because then they can be deformed by the ignition pulse. If this occurs, the propellant bed might be compressed so tightly that the ignition gases might not percolate satisfactorily through the bed. A number of physical properties of propellants are occasionally of interest to the ammunition designer. Among these properties are thermal expansion, thermal conductivity, specific heat, and thermal diffusivity. The following properties are of direct interest to the charge designer:

a. *Density*. Conventional single and double-base propellants have values of approximately 1.60 grams per cubic centimeter, while triple-base (nitroguanidine) propellants are slightly higher. This is advantageous for tank ammunition where the maximum amount of propellant charge is required to meet the desired ballistic levels.

b. *Bulk Density*. This often is referred to by such terms as "gravimetric density" and "screen loading density" depending on the test utilized. The values reported are empirical and are greatly dependent on the specific gravity of the propellant, the grain geometry, surface characteristics, and the measuring technique.

The term "bulk density" often is confused with loading density, a term that the ballistician uses for the ratio of the charge weight in a system to the chamber volume.

c. *Compressibility of Grains*. This is a measure of how much a propellant grain can be compressed before cracks appear. The usual required minimum value for gun propellants at 25°C is 30 percent. That value is based on historical experience.

9-5. Manufacture. The manufacturing methods for various types of propellants are given below.

a. *Single-Base Propellants*. The manufacture of nitrocellulose is discussed in chapter 8. Wet nitrocellulose from the manufacturing process is dehydrated after the moisture content has been reduced to approximately 28 percent by wringing. Dehydration is accomplished by pressing the nitrocellulose at low pressure so as to squeeze out some water, adding 95 percent ethanol, and pressing at about 24,133 kilopascals (3,500 pounds per square inch). A block containing 11.4 kilograms (25 pounds) of dry nitrocellulose and about one-third that much of 90 percent ethanol is obtained. The wet block is broken up into small lumps by means of a rotating drum containing iron prongs and a screen. The nitrocellulose is transferred to a watercooled mixing machine of the dough-mixer type and, while this is in operation, ether equal to approximately two-thirds of the weight of dry nitrocellulose is added.

Any plasticizing agents and stabilizers to be included in the composition are dissolved in or mixed with the ether prior to addition to the nitrocellulose. After addition of the ether is complete, materials such as potassium nitrate are added. Mixing of the ingredients is continued for about one hour. A partially colloided mixture which resembles dry oatmeal is produced. By pressing this at approximately 20,685 kilopascals (3,000 pounds per square inch) so as to form a block, the degree of colloiding is increased rapidly. This effect is further increased and uniformity of the mixture is improved by subjecting it to a pressure of about 24,133 kilopascals (3,500 pounds per square inch) in a macaroni press.

Here the material is squeezed through a series of screens and perforated plates and emerges in a form resembling that of macaroni. This is pressed again to form a block of well colloided material. This is placed in a graining press and extruded through a carefully designed die by the application of pressure. The material emerges as a cord with one or more cylindrical perforations.

The cord is cut into pieces of predetermined length. Removal of the volatile solvent, with shrinkage of the grains to their final dimensions, is accomplished by three operations. In the solvent recovery operation, the powder is placed in a large tank and warm air or other gas is passed through the mass. With careful control, so as to prevent surface hardening, the temperature of the air is gradually increased to not more than 65°C. The solvent recovery operation requires from 2 to 14 days, depending upon the size of the grain, and reduces the solvent content to approximately six percent. The water dry operation consists of placing the partially dried powder in water at about 25°C and gradually increasing the temperature to a maximum of 55°C. After a number of days, the residual solvent is reduced to 0.3 to 5 percent, depending upon the grain size. The powder now is air dried to remove surface moisture and screened to remove dust and grain clusters. The final operation before packing is to blend all the powder in a lot, which may vary from 22,700 to 227,000 kilograms depending on the type of powder. This is accomplished by transferring the powder from one conical bin to another by gravity flow. This blending improves uniformity of the lot with respect to composition and external moisture content.

b. *Double-Base Propellants*. Double-base propellants are manufactured by two methods. The solvent process is similar to that used for single-base powders except that a mixture of ethanol and acetone is used as the solvent and the solvent recovery procedure is omitted because of the hazard involved in recovering solvents containing nitroglycerin. The solventless process is used when the nitroglycerin and any other colloiding agents constitute approximately 40 percent of the composition. In this process the wet nitrocellulose is blended with the nitroglycerin in a tank filled with water. Ethyl centralite is mixed in and the bulk of the excess water is removed by centrifuging. The resulting paste is put in cotton bags and subjected to heated air currents to reduce the moisture content. The remaining constituents are then blended with the partly dried paste. Repeated rolling between heated steel rollers removes the rest of the water and completes colloiding of the nitrocellulose. The thickness of the sheet formed is controlled carefully and varies with use. If the sheet is to be cut into flakes for use in small arms or mortars, the thickness is between 0.08 and 0.32 millimeter (0.003 and 0.0125 inch). Sheets to be extruded in the form of large grains for use in rockets may be as thick as 3.18 ' millimeters (0.125 inch).

c. *Triple-Base Propellants.* The manufacturing process used for the nitroguanidine triple-base propellants in the United States has been uniformly solvent extrusion. The amount of solvent used is quite low so the propellant is very soft during extrusion. The soft strands may require partial drying before cutting in order not to deform the cross section at the cut. Removal of solvent from the triple-base propellant is rapid, possibly due to diffusion of solvent within the grain along the crystal-plastic interfaces. In order to make a good quality grain, lower drying temperature gradients are used in order to avoid steep solvent gradients resulting in distortion and cracking.

d. *Composite Propellants*. A composite propellant is manufactured by a simple mixing operation, cured, and molded into grains or poured directly into the rocket case and cured by heating in controlled ovens.

Operational temperatures extend from -40° to +60=C.

The high solid content requires great resin strength and good elastic properties to withstand low temperatures.

Precise control of the oxidizer particle size is needed to control ballistic properties. Rockets up to 6.6 meters in diameter and weighing up to 45,400 kilograms have been fired successfully. The dense smoke produced by these propellants limits their use to long range systems where the signature of the rocket does not easily reveal the firing point.

e. *Ball Propellants*. Ball propellants are used for small arms. The nitrocellulose used to make the propellant is extracted from waste single-base propellant. To produce the propellant in ball form, water-wet nitrocellulose is mixed with ethyl acetate, colloided with animal glue, and agitated; excess water causes the propellant to precipitate in a ball. The animal glue is washed away using hot water. The propellant is screened to size and nitroglycerin is added in the presence of ethyl acetate. The nitroglycerin is absorbed by the ball propellant, the ethyl acetate is driven off, and the ball is carried to a roll mill to cause cracks, that serve as combustion sites, to form in the ball. The propellant is then dried and a deterrent coating such as Dibutylphthalate is added. The deterrent reduces the burn rate of the propellant to an acceptable level.

9-6. Propellant Grain Geometry. The burning time of a propellant charge depends on two factors. One factor is the velocity at which the exothermic decomposition reaction occurs. This is called burning rate. The other factor is the total surface area of propellant exposed. In order to control the surface area available for reaction, propelling charges consist of numerous propellant grains. Propellant grains can have a variety of shapes as shown in figure 9-1. An additional grain geometry, the flake, is also used in mortars. The shape of the grain determines how much surface area is exposed as burning proceeds. For example, as a cord burns, the surface area of exposed propellant decreases. This is called a degressive grain. As a single perforated grain burns, the exposed surface area remains nearly constant because the outer surface area decreases as the inner surface area increases. This is called a neutral grain. In a progressive grain, for example the multi-perforated and rosette, the surface area increases during burning. The grain geometry and burning rate are interrelated. The burning time of a propelling charge that contains a propellant with a high burning rate and strongly digressive grain geometry could be equal to the burning time of a charge that contains a propellant with a low burning rate and strongly progressive grain geometry. European nations have favored the use of single perforation, strip, and cord propellants. The United States uses single perforation and multi-perforation propellants. The single perforation grains may be slotted or unslotted. The slotted grain has the desirable characteristic of venting gas during combustion. All countries use ball propellants for small arms. In a multi-perforation or rosette grain that consists of a propelling compound with a specific linear burning rate, the burn time can be varied by varying the web thickness. The web thickness, shown in figure 9-2, is the average dimension of the outer web and inner web. In general, the finer the web the shorter is the burning time of the propellant charge. The grain dimensions also influence the burning time. The finer the web the higher the pressure produced. A cannon is designed to operate with a maximum pressure. This pressure must be taken into account when designing the grain web. The same projectile velocity can be attained with a smaller amount of propellant with fine web and with a larger amount of propellant with a coarse web. However, the pressure with the former is considerably greater than the latter. In general, the heavier the projectile or the greater the prescribed velocity, the larger the powder grain and web used. As shown in figure 9-2, the burning of a seven perforation grain produces 12 unburned slivers or pieces of triangular cross section that represent approximately 15 percent of the total weight of the grain. These slivers burn digressively and usually are burned in the bore of the weapon; but if the tube is relatively short or a reduced charge of propellant is fired, incompletely burned slivers may be expelled from the muzzle. The rosette or Walsh grain (figure 9-1) with a scalloped outer periphery, reduces the number of slivers produced by a multi-perforation grain and therefore reduces or eliminates the amount of unburned powder ejected. In practice, there are certain general relationships between the dimensions of powder grains. These dimensions must remain within fairly narrow limits. Specification requirements for cannon powders include the relative dimensions which follow.

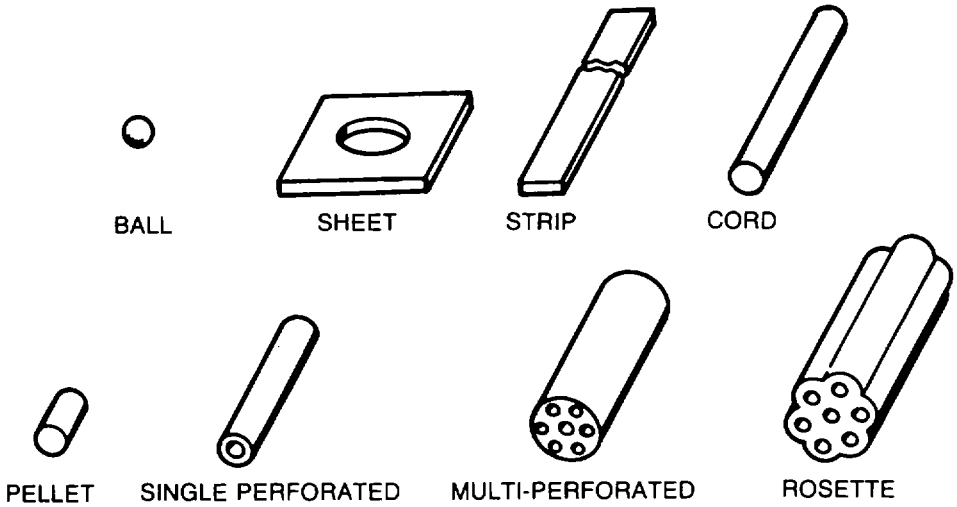


Figure 9-1. Typical shapes of propellant grains.

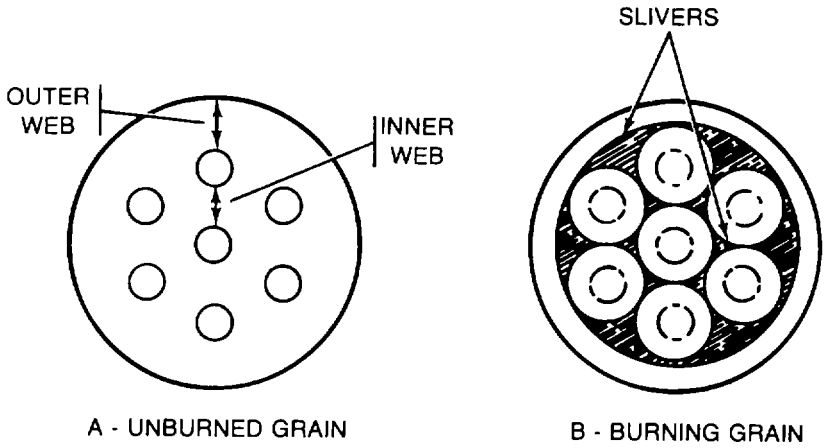


Figure 9-2. Web thickness and direction of burning through a progressively burning grain.

a. The ratio of average grain length (L) to average grain diameter (D) is 2.10 to 2.50 for multi-perforation grains and 3 to 6 for single perforation grains.

b. The ratio of average grain diameter (D) to the average diameter of perforations (d) is 5 to 15 for multi-perforation grains and approximately three for single perforation grains.

c. The difference between the average outer web thickness (Wo) and the average inner web thickness (Wi) of multi-perforation powder is not more than 15 percent of the average web thickness (Wa).

9-7. Burning Rates. Ballisticians view the propellant grains as burning in parallel layers, where the burning proceeds in a direction perpendicular to the surface. This universally accepted concept is known as Piobert's law and is supported by the experience of many investigators drawing their conclusions from many different approaches. The linear burning rate vs pressure behavior of a gun propellant (the rate at which burning proceeds normal to the surface) is a characteristic of the composition and is a required input for most interior ballistics calculations.

a. The burning rate is independent of grain geometry. Results of the two tests usually used to determine burning rates (the strand burner and closed bomb) are the same for cord, single perforation, and seven perforation grains. The closed bomb is used most commonly to determine relative force (RF) and relative quickness (RQ) of gun propellants. In this determination, a test propellant is fired in a closed bomb and the results are compared with those obtained with a reference propellant fired under identical conditions. RF is defined as

$$RF = \frac{P_{max} \text{ test propellant}}{P_{max} \text{ reference propellant}}$$

RQ is defined as

$$RQ = \frac{dP/dt \text{ test propellant}}{dP/dt \text{ reference propellant}}$$

where dP/dt is the rate of change of pressure with time.

b. Burning rate vs pressure data commonly are fitted to an equation of the form

$$r = bP^n$$

known as de Saint Robert's equation. Plots of the log of the burning rate vs the log of the pressure of many propellants yield straight lines. Under that condition, b and n are constants. Table 9-3 gives values of b and n for several of the standard propellants. Using the values specified, the burning rate equation yields r in inches per second when P is in pounds per square inch.

Table 9-3. Burning Rate Parameters for Several Standard Gun Propellants

Propellant	M1	M2	M6	M10	M30
b	0.002143	0.002432	0.002989	0.004004	0.00576
n	0.710	0.755	0.702	0.695	0.652

c. The burning rate of gun propellants generally increases with initial propellant temperature. The temperature coefficient of the burning rate is defined as the ratio of the change in burning rate and the change in temperature at constant pressure. Typical values for the temperature coefficient are 0.077 percent per degree centigrade at 206,850 kilopascals (30,000 pounds per square inch) for M 10 and 0.05 percent for M30 under the same conditions.

d. The burning rate of conventional propellants increases with increasing flame temperature. Several empirical correlations have been developed which provide a means for estimating burning rates of different propellant formulations from the adiabatic flame temperature.

e. Propellants used in small arms usually have a deterrent impregnated into their surface which alters the chemical composition of the outer portion of the grains to slow the initial burning rate. Commonly used deterrents include dinitrotoluene and ethyl centralite. The deterrent has a moistureproofing effect and usually a melting point of less than 1 00°C. A coating of deterrent is applied by tumbling the propellant powder in a "sweetie" barrel in a water slurry with the deterrent at a temperature above the melting point of the deterrent.

f. The burning rate of solid propellants increases with increasing product gas velocity near the surface.

This phenomenon is referred to as erosive burning. The extent of erosive burning depends on grain geometry and composition. Relatively "hot" propellants are apparently less subject to erosive burning than are "cool" ones. The inner surface of long tubes does not, apparently, burn in an even, uniform manner. The holes increase in size faster at the ends. Slotted tubes burn closely in conformance to Piobert's law.

g. The actual burning rate of solid propellants also deviates from the steady-state or expected value under rapid pressure excursions. That is, the instantaneous burning rate then will differ significantly from that expected for the corresponding instantaneous pressure. This phenomenon, called dynamic burning, has not been studied enough to present corrections to the burning rate equation.

9-8. Ignitabllity. Ignition of a propellant charge is accomplished by raising the temperature of the propellant surface to the ignition temperature. The simultaneous ignition of all the exposed surfaces is desirable for many gun applications. Black powder is used extensively for artillery and rocket propelling charge ignition.

Black powder is a more efficient igniter than finely divided propellant, which is used in mortars, because it does not produce as much gas per unit weight as propellant, its use reduces ignition shock, it yields high initial pressures, and the hot particles in its combustion products assist in transferring heat to the propellant surface.

a. An increase in the nitrogen content of the nitrocellulose causes slight increase in ignitability.

b. The substitution of nitroglycerin for part of the nitrocellulose in a composition increases ignitability to a marked extent.

c. The inclusion of an inert, gelatinizing agent, such as Dibutylphthalate or triacetin, in a propellant composition results in a decrease in ignitability.

d. The inclusion of TNT or dinitrotoluene in a composition causes measureable decrease in ignitability.

e. The inclusion of five percent or less of potassium nitrate in a composition causes a significant increase in ignitability.

f. The presence of a deterrent on a propellant causes retardation of ignition.

g. As the initial temperature of the propellant decreases, the ignitability decreases.

9-9. Charge Design Considerations. The selection of a propellant for a particular application is determined by cost, by the interior ballistics requirements, by propellant/weapon interface considerations, and by limitations with respect to muzzle effects. The propellant with the lowest cost formulation and the lowest flame temperature that still will meet the velocity and pressure requirements is generally used. Other important considerations are the effects on ballistic performance of various propellant grain shapes and the problem of matching the gas production rate

from propellant burning to the rate of increase of volume in the gun behind the accelerating projectile. The shape of the grain also affects the amount that can be loaded in a given space and can control the generation of pressure waves in large caliber guns. The charge weight sometimes is restricted in large caliber guns by the momentum limit. The gas expelled from the muzzle adds to the total forward momentum. The propellant charge plays a major role in gun fouling and erosion. This field is receiving considerable attention at this time and in recent years, erosion often has been reduced dramatically by means of wear-reducing materials that are added to the propellant composition or to the charge as cartridge case liners. Efforts usually are made to minimize muzzle flash and smoke. Muzzle flash and smoke are related in a sense and have been investigated extensively. Two components contribute to muzzle flash: the primary flash and the secondary flash. The primary flash is caused by incandescent hot gases emerging from the muzzle or heated to incandescence by the shock following the projectile out of the gun. The secondary flash is caused by the burning of combustible muzzle gas when mixed with air and heated to ignition by the shock wave. Ignition of the gas cloud is also caused by the early, bright burning of tracers. This is a voluminous, relatively long lived event and is far more objectionable than the primary flash. In small caliber weapons, secondary muzzle flash is suppressed effectively in many weapons by means of mechanical devices attached to the muzzle. Various chemical additives, especially alkali metal salts, are very effective and widely used to suppress secondary flash. The salts may be incorporated into the compositions, or they may be loaded as separate components in the charge. Secondary flash is also reduced by reduction of the propellant composition flame temperature and by reduction of the proportion of combustible gases produced by the propellant. Gun smoke is due to particulate, usually inorganic, material emerging from the gun behind the projectile. Primer and igniter combustion products, barrel scrapings, and solid combustion products from the propellants are the major constituents of gun smoke. The visibility of the smoke or smoke density is due largely to the products from the alkali metal salt flash suppressant. These constituents also are responsible for the substantial increase of smoke density under humid conditions.

9-10. Ballistic Effects. The study of the combustion of a propellant in a confined volume, and the resultant rate of gas generation combined with its effect on the acceleration of a projectile, is called interior ballistics. Figure 9-3 shows a representative pressure travel curve for a projectile in a gun. The further the point of maximum pressure (points A, B, and C) is from the powder chamber, the greater the velocity acquired by the projectile. This is the reason the United States favors the use of multiperforated grains.

a. There are four general equations which form the basis of interior ballistics.

(1) The burning rate equation is the first of the four. This equation has already been discussed.

(2) The equation of the form takes into account the propellant grain geometry. The web fraction, Wf, is defined by the equation:

$$Wf = \frac{2Rrdt}{Wo}$$

where r is the burning rate, R is the burning rate conversion factor, and Wo is the original web thickness. The factor of two is present since the web is being burned from two opposite surfaces and R is included to compensate for burning rate peculiarities. The amount of gas generated can be found as a function of We by the following two equations:

$$\frac{G}{C} = f(W_I) = K_0 + K_1 W_I + K_2 W_I^2 = K_3 W_I^3 \text{ if } W_I \geq 0$$

$$\frac{G}{C} = f(W_I) = K_0 + K_1' W_I = K_2' W_I^2 + K_3' W_I^3 \text{ if } W_I \leq 0$$

where G is the mass of gas generated, C is the original charge mass, Ko-K3 and K'-K3are coefficients determined by the grains geometry and Wi is the fraction of web remaining. The first equation is employed during non-splintered burning (WtO0) and the second is used after grain splintering has occurred (WI<0). Slivering is typical of multi-perforation grain types. In these grain types there is residual propellant when the web fraction is burned to zero. This remaining propellant is then burned as slivers. In simulations containing more than one grain type, each granulation is handled separately. The total gas generated is simply their sum.

(3) As propellants burn, the total energy available from a unit mass of propellant can be computed by the equation:

$$E = \frac{FG}{g\text{-}1}$$

where E is the energy liberated, G is the ratio of specific heats of the propellant gas, F is the propellant impetus

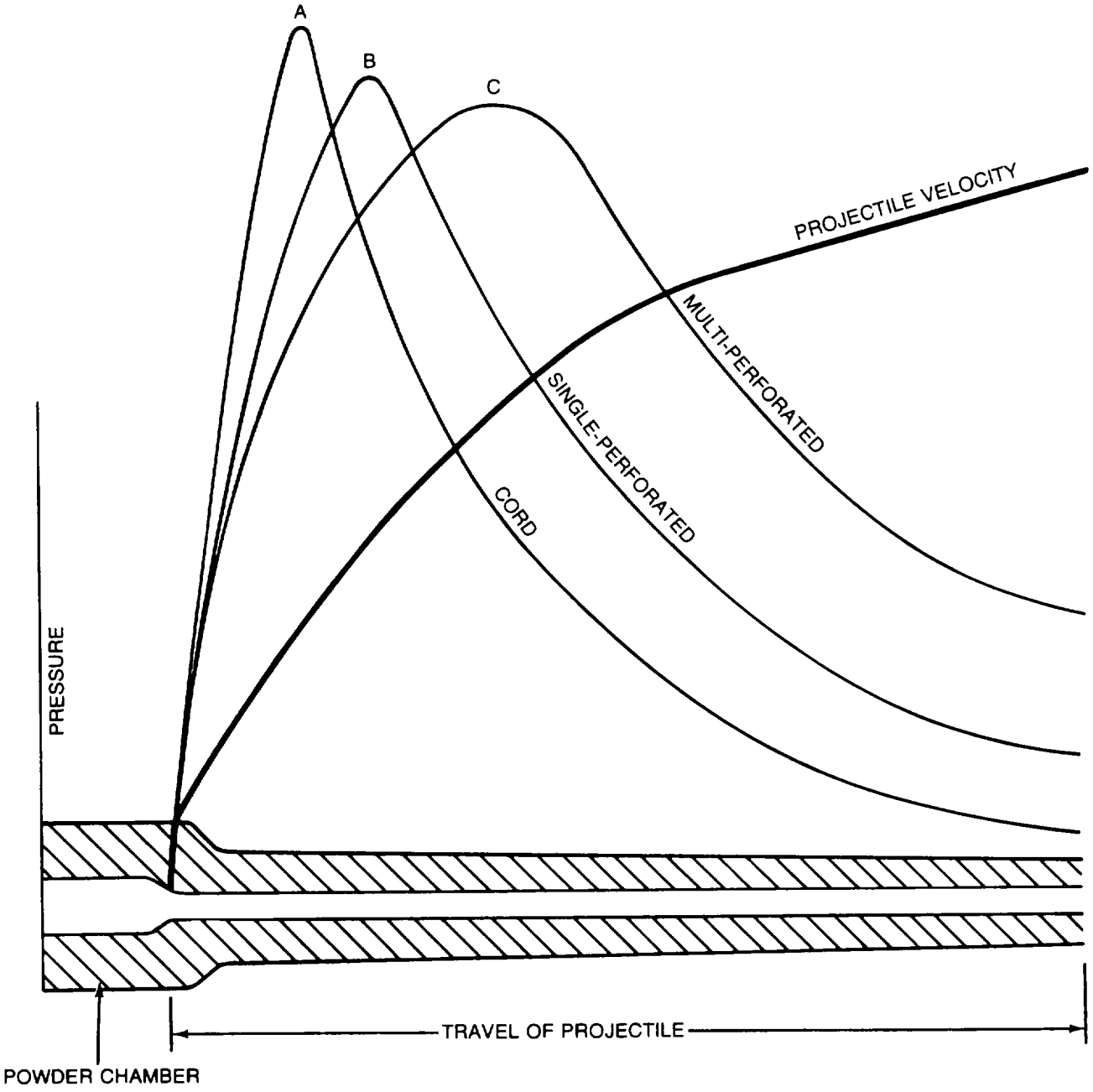


Figure 9-3. Pressure travel curves for a projectile in a gun.

(the amount of energy per unit mass). In cases where more than one grain type or more than one propellant type are used, the energy generated by each distinct granulation-propellant combination is calculated separately and summed to compute the total energy released. The energy released by the burning propellants is dissipated in several ways. The potential energy of the confined gas is increased (PV energy). Energy is spent accelerating the projectile and the gas itself (kinetic energy). Energy is lost through thermal and frictional processes which results in an increase of the gas temperature. The energy balance equation is

$$\frac{PE}{\gamma - 2} = E - (0.5 M_{eff} V^2)(1 + B_f)$$

where PE is the potential energy of the confined gas, E is the total energy released by the propellants, Meff is the effective mass of the projectile and gases, Bf is the energy loss coefficient, V is the velocity of the projectile, and y is the specific heat ratio of the propellant gas. The effective mass used in this calculation is given by the equation:

$$M_{eff} = W_t . CF3 . M_p$$

where W_t is a correction for projectile twisting, CF3 is a Piddock-Kent coefficient, and M_p is the projectile mass. The factor Wt is included since the projectile is undergoing rotational acceleration in addition to linear acceleration. Wt is normally set at 1.02 which provides an excellent approximation.

(4) Projectile motion is determined by the application of Newton's third law

$$a = \frac{P_B A}{M_p}$$

where a is the projectile's acceleration, Pe is the base pressure, A is the bore cross sectional area, and Mp is the projectile's mass. The velocity and position may be obtained by integrating this expression one and two times, respectively with respect to time.

b. Several computer programs are used to perform interior ballistic calculations. One such program is the Interior Ballistic Interactive Simulation (IBIS) code. IBIS computes propellant charge weight, web dimensions, and grain dimensions from the pressure parameters of the cannon, projectile weight, muzzle velocity, bore cross sectional area, force of the propellant, and burning rate of the propellant.

9-11. Sensitivity. The colloidal structure of propellants reduces sensitivity to a point well below that of the individual ingredients, nitroglycerin and/or nitrocellulose. From a practical standpoint, the hazards associated with a propellant are mainly heat, spark, and very high energy impact.

a. To a great extent, the degree of confinement determines whether a propellant will deflagrate or detonate. Experiments have shown that the confinement afforded by the upper part of a column of propellant may be sufficient to cause explosion if the powder at the bottom of the pile is ignited. Various powder compositions were found to have correspondingly varying critical heights of column, the critical height varying inversely with the energy content of the composition. For the same composition, the critical height was found to vary directly with the average web of the powder. If the temperature of the powder is 50°C instead of 20°C, the critical height of a composition is only 30 to 50 percent as much as at the lower temperature. Propellants for small arms, chiefly nitrocellulose, were found to have critical height values of 38.1 to 50.8 centimeters. Single based cannon powders of larger grain sizes and containing moderants have critical height values of 76.2 centimeters or more. Propellants can be detonated by initiating compounds or booster explosives.

b. Propellants are sensitive to electric sparks only if the material is in the form of a dust. Some test results indicate the powder dust is much more ignitable by a static electricity spark than is nitrocellulose. Dry-house and blending-towerfires have occurred that were attributed to the primary ignition of powder dust by static electricity sparks. Atmospheric relative humidity above 60 percent prevents such spark discharges and ignitions. The humidity must be measured where the operation is going on.

c. Propellants can be ignited by the friction and impact of small arms bullets. Detonation or deflagration occurs according to confinement. Recently a great deal of attention has been placed on very high kinetic energy impacts such as the impact of a shaped charge jet spall. These concerns are obviously from the standpoint of practical application.

9-12. Stability. The stability of nitrocellulose, which was discussed in Chapter 8, is relatively poor. The stability of nitrocellulose based propellants is correspondingly poor. The degradation of nitrocellulose proceeds by two chemical reactions. In the first degradation reaction, nitrocellulose loses nitrogen oxides. The loss of nitrogen oxides

is an intrinsic tendency of the nitrocellulose molecule. The reaction rate varies with the temperature, but even at low temperatures the loss of nitrogen oxides occurs. In the second degradation reaction, which occurs initially as a result of the first, the nitrogen oxides that are formed attack the nitrocellulose molecule. The reaction between the nitrocellulose and nitrogen oxides produces more nitrogen oxides. The increased number of nitrogen oxides and increased temperature cause the reaction rate to accelerate. After a few years the reaction rate in samples of sufficient size is so fast that the propellant self-heats above the flame point and will self-ignite. Nothing can be done to stop the first degradation reaction. The second degradation reaction is controlled by two means. The heat of reaction is dissipated by a suitable heat sink, for example the metal case of a cartridge is an excellent thermal conductor. This does not solve the problem totally, however, if the diameter of the cartridge case exceeds 3 inches. The second, and most effective, means of controlling the degradation reaction is to include a chemical stabilizer in the propellant composition. A stabilizer has a greater affinity for the nitrogen oxides than nitrocellulose, and so absorbs them before they can attack the nitrocellulose molecule. This reduces the rate of propellant decomposition to about that of the first degradation reaction. However, the stabilizer is consumed as it absorbs nitrogen oxides. Therefore the increase in time the propellant will remain stable is directly proportional to the amount of stabilizer added. Some propellants can be stabilized in this manner for 30 or 40 years. Three stabilizers are of interest for military applications in the United States; diphenylamine (DPA), ethyl centralite (EC), and the akardites (AK). DPA is used in single-base propellants but is incompatible with nitroglycerin and so cannot be used in double-base and triple-base compositions. EC or 2-NDPA is used for double and triple-base propellants which use nitroglycerin as the gelatinizing agent for the nitrocellulose. Akardites are used in propellants that contain DEGN rather than nitroglycerin.

a. Diphenylamine, $(C_6H_5)_2NH$, is an ammonia derivative in which two of the hydrogens have been replaced by phenyl groups. Each phenyl ring has three hydrogens which can be replaced with nitro groups.

Therefore, DPA can be nitrated to the hexanitrate by absorbing the nitrogen oxides produced during the decomposition of nitrocellulose. DPA is nitrated relatively easily and the reaction is not exothermic. During the decomposition of nitrocellulose, DPA nitrates to the following compounds in succession.

N-nitrosodiphenylamine
2-nitrodiphenylamine
4-nitrodiphenylamine
N-nitroso-2-nitrodiphenylamine
N-nitroso-4-nitrodiphenylamine
4,4', 2,4', 2,2', and 2,4-dinitrodiphenylamines
N-nitroso-4, 4'-dinitrodiphenylamine
N-nitroso-2, 4'-dinitrodiphenylamine
2, 4, 4' and 2, 2', 4-trinitrodiphenylamines
2,2', 4,4'-tetranitrodiphenylamine
2,2', 4,4', 6-pentanitrodiphenylamine
Hexanitrodiphenylamine

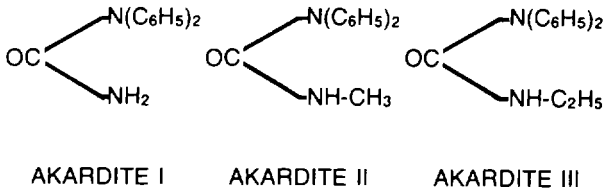
The propellant does not start to become unstable until most of the diphenylamine has been converted to hexanitrodiphenylamines. A very accurate test to measure the remaining safe storage life in a propellant lot is to analyze the distribution profile of the nitro DPAs. Only about one percent DPA can be added to a propellant because its nitrated products change the ballistic properties.

b. Centralite I (which is also called ethyl centralite or symmetrical diethyldiphenylurea), OC [N-(C2H5) (C6H5)]2, was developed in Germany for use in double base propellants. The compound acts as a stabilizer, gelatinizer, and waterproofing agent. Unlike diphenylamine, centralite can be used in relatively large proportions and some propellant compositions contain as much as eight percent of this material. Like diphenylamine, centralite is nitrated by the products of nitrocellulose decomposition. The following compounds are formed successively, as many as four being present simultaneously, as deterioration of the powder proceeds.

4-nitrocentralite
4,4' dinitrocentralite
N-nitroso-N-ethylaniline
N-nitroso-N-ethyl-4-nitraniline
2,4, dinitro-N-ethyl-aniline

Centralite II (which is also called methyl centralite or symmetrical dimethyl diphenylurea), OC[N(CH3) (C6H5)]2, also has been used as a stabilizer but is not considered to be as effective as the ethyl analogue.

c. Three akardites, or acardites, are used to stabilize propellants. Their structure is shown in figure 9-4. Akardite II is often used in DEGN containing propellants.



AKARDITE I AKARDITE II AKARDITE III

Figure 9-4. Akardites.

CHAPTER 10
UNITED STATES PYROTECHNICS

10-1. Categories of Pyrotechnic Devices.

a. General. All pyrotechnic compositions contain oxidizers and fuels. Additional ingredients present in most compositions include binding agents, retardants, and waterproofing agents. Ingredients such as smoke dyes and color intensifiers are present in the appropriate types of compositions.

(1) Oxidizers are substances in which an oxidizing agent is liberated at the high temperatures of the chemical reaction involved. Two oxidizing agents, oxygen and fluorine, are currently used in pyrotechnic compositions. Oxygen is provided by the nitrates of barium, strontium, sodium, and potassium, the perchlorates of ammonium and potassium, or the peroxides of barium, strontium, and lead. Use of a specific oxidant is determined by the desired burning rate, luminosity, and color. Fluorine is usually provided by polytetrafluoroethylene or chlorotrifluoroethylene. Pyrotechnic compositions do not usually contain a stoichiometric proportion of oxidizer, the balance of the requirement for fuel oxidation is provided by atmospheric oxygen.

(2) Fuels include finely powdered aluminum, magnesium, metal hydrides, red phosphorus, sulfur, charcoal, boron, silicon, and suicides. The most frequently used are powdered aluminum and magnesium.

Additional materials such as binding agents, waterproofing agents, and color intensifiers also act as fuels.

(3) Binding agents include resins, waxes, plastics, and oils. These materials make the finely divided particles adhere to each other when compressed into pyrotechnic items. They also prevent segregation and ensure a more uniformly blended composition. Binders also help to obtain maximum density and increased burning efficiency. In addition, they serve, in some cases, to reduce the sensitivity of compositions that otherwise would be unduly sensitive to shock and friction.

(4) Retardants are materials that are used to reduce the burning rate of the fuel-oxidizing agent mixture, with a minimum effect on the color intensity of the composition. Some retardants act only as inert diluents, while others take part in the combustion reaction at a much slower rate than the metallic fuels. Calcium carbonate, sodium oxalate, strontium resinate, titanium dioxide, polyvinyl chloride, ethyl cellulose, paraffin, linseed oil, castor oil, asphaltum, and sulfur are the most important retardants used. Certain of these serve other purposes as well. For example, sodium oxalate and polyvinyl chloride act also as color intensifiers, titanium dioxide is a source of incandescent solid particles in the flame produced by the composition, and the waxes and oils act as fuels, binding agents, and waterproofing agents as well as retardants.

(5) Waterproofing agents are necessary in many pyrotechnic compositions because of the susceptibility of metallic magnesium to reaction with moisture, the reactivity of metallic aluminum with certain compounds in the presence of moisture, and the hygroscopicity of nitrates and peroxides. Waterproofing agents are applied as a coating on metallic fuels, such as a coating of dried linseed oil on magnesium, or as an ingredient uniformly distributed throughout the rest of the composition. In some cases, the metallic fuel is given a coating by treatment with a solution of acidic or acidified potassium dichromate. Waxes, resinates of metals, and natural and synthetic resins are used for distribution throughout the composition. Many of these serve also as binding agents.

(6) Color intensifiers are highly chlorinated organic compounds such as hexachloroethane (C_2Cl_6), hexachlorobenzene (C_6Cl_6), polyvinyl chloride, and dechlorane ($C_{10}Cl_{12}$). These agents are effective because of their decomposition during combustion and the formation of metallic chlorides which produce characteristic color bands in the flame spectrum. The portion of the intensifier other than chlorine acts as a part of the fuel in the composition. Since they are less reactive than metallic fuels, color intensifiers act to some extent as retardants of combustion. Certain intensifiers such as polyvinyl chloride, because of their physical characteristics, can serve also as binding agents.

(7) Smoke dyes are azo and anthraquinone dyes. These dyes provide the color in smokes used for signaling, marking, and spotting.

b. Flares and Signals.

(1) The illumination provided by a flare is produced by both the thermal radiation from the product oxide particles and the spectral emission from excited metals. The human eye is more sensitive to the frequencies produced by sodium, so sodium nitrate is usually chosen as the oxidant. The composition of illuminating flares falls in the range of 53 to 58 percent magnesium, 36 to 40 percent sodium nitrate, and four to eight percent binder. Aluminum may also be used as a fuel. The three qualities which are useful in describing the performance of flares are intensity, illuminance, and light efficiency. The intensity (I), expressed in candelas is determined experimentally. The intensity of a flare is largely determined by the combustion temperature which depends on the stability of the products. 3000°K should be exceeded to accommodate the spectral sensitivity of the human eye. Illuminance (E), expressed in lumens per square meter, depends on the distance of the flare from the features that are to be illuminated. The approximate equation for illuminance is:

$$E = Ih\,(r^2+h^2)^{3/2}$$

where h is the height of the flare above the ground and r is the radius of illumination. Light efficiency (C), expressed in lumens per watt, is the light output per unit energy in terms of the heat of reaction of the flare mixture burning in air. The approximate equation for lighting efficiency as a function of time is

$$C = 4It/Qm$$

where Q is the heat of reaction, m is the mass of the mixture, and t is the time. The volumetric efficiency of a flare is the radiant energy per steradian per unit flare volume which is expressed in watt seconds per steradian cubic centimeter. A full description of a flare is given by the volumetric efficiency, burning time, and spectral distribution. Infrared flares are used with a scanning device such as a low light level television or image intensifier. These flares use metals with peak spectral emissions in the infrared rather than sodium. Table 10-1 lists the composition of some infrared flare mixtures as a function of the wave length of the light emitted. A special type of flare is a thermal decoy which has a strong infrared emission. One of the reactions utilized in decoys is the reaction between magnesium and a fluorocarbon such as polytetrafluorethylene. Hot carbon particles are formed which provide infrared emissions.

Table 10-1. Infrared Flare Formulas

	Wavelength emitted in micrometers		
Component	0.76	0.79	0.8 - 0.9
Silicon (%)	10	10	16.3
KNO3 (%)	70	-	-
CsNO3 (%)	-	-	78.7
RbNO3 (%)	-	60.8	-
Hexamethylene tetramine, (%)	16	23.2	-
Epoxy resin, (%)	4	6	5

(2) Signal flares are smaller and faster burning than illuminating flares. Various metals are added to these compositions to control the color of the flame.

Combinations of metals may also be used to prevent enemy imitation of flare sequences. One example is the red-green flare. The composition is given in table 10-2.

Table 10-2. Red-Green Flare System, Parts by Weight

Barium nitrate	30
Strontium nitrate	13
Potassium perchlorate	9
Magnesium	30
Dechlorane	12
Polyvinyl acetate resin	4

The color of the flare is different when viewed through a filter than when viewed without a filter. Unfiltered, the green and red lights combine to form a yellow light which resembles the color of a pure yellow flare.

c. Colored and White Smoke.

(1) The pyrotechnic generation of smoke is almost exclusively a military device for screening and signaling. Screening smokes are generally white because black smokes are rarely sufficiently dense. Signal smokes, on the other hand, are colored so as to assure contrast and be distinct in the presence of clouds and ordinary smoke. Smoke has also been found to aid the daytime observance of tracer projectiles and also for tracking space vehicles during launch. Whereas smokes are often characterized by the mode of their formation, any concentrated suspension of particles ranging from 0.01 to about 5.0 micrometers can be considered a smoke. These particles, when suspended in air, reflect, scatter and absorb radiation. The following are pyrotechnic methods for smoke generation as opposed to mechanical methods such as atomization of fog oil, of titanium tetrachloride (FM smoke), or of sulfur trioxide.

(a) Venturi thermal generator type. The smoke producing material and the pyrotechnic fuel block required to volatilize the smoke material are in separate compartments. The smoke producing material is atomized and vaporized in the venturi nozzle by the hot gases formed by the burning of the fuel block. An example of this type smoke generator is the oil smoke pot which is powered by a slow burning, gassy pyrotechnic mixture such as ammonium nitrate and ammonium chloride with a small amount of carbonaceous fuel. The resulting gas jet pulls a stream of oil from a reservoir and injects it into a venturi where the formation of the aerosol takes place.

(b) Burning type. Burning type smoke compositions are intimate mixtures of chemicals. Smoke is produced from these mixtures by either of two methods. In the first method, a product of combustion forms the smoke or the product reacts with constituents of the atmosphere to form a smoke. In the second method, the heat of combustion of the pyrotechnic serves to volatilize a component of the mixture which then condenses to form the smoke. White phosphorus, either in bulk or in solution, is one example of the burning type of smoke generator. The resulting colloidal suspension of phosphorus pentoxide is quickly hydrolyzed by moisture to become phosphoric acid droplets which are the actual visible constituent of the smoke. Various other burning type smoke generators exist such as those used for signaling purposes and those which use red phosphorus, metallic phosphides, or phosphorus trichloride as the source of the particulate cloud. Another important burning type of smoke generator is the HC smoke mixture which has been prepared with a number of combinations of zinc with a chlorine carrier to form, on combustion, zinc chloride. For example,

$$2Al + C_2Cl_6 + 3ZnO \rightarrow A1_2O_3 + 2C + 3ZnCl_2$$

(c) Explosive dissemination type. The smoke producing material is pulverized or atomized and then vaporized, or a preground solid is dispersed by the explosion of a bursting charge. The explosive dissemination smoke generator may contain metallic chlorides which upon dispersal, hydrolyze in air. Examples are titanium, silicon, and stannic tetrachloride. An effective smoke agent, whether mechanically dispersed from an aircraft spray tank or vaporized thermally, is a mixture of sulfur trioxide and chlorosulfonic acid (FS smoke agent) which upon hydrolysis forms sulfuric and hydrochloric acid dispersions. Of course, all such formulations are highly corrosive, and, if not outright toxic, then conducive to pulmonary edema. The so-called standard smoke is a smoke of such a density that a light of 25 candela intensity is just invisible when observed through a layer of approximately 30 meters. The amount of smoke agents required to produce one cubic meter of standard smoke is given in table 10-3.

Table 10-3. Amount of Smoke Agent per Cubic Meter of Standard Smoke

Material	Grams per cubic meter
White phosphorus	0.064
Sulfur trioxide	0.099
FS agent	0.116
HC mixture	0.127
FM agent	0.159
Crude oil	2.11

(2) The preferred method of dispersing colored smokes involves the vaporization and condensation of a colored organic volatile dye. The problem has always been one of selecting dyes which are thermally stable and which vaporize without decomposition at temperatures below 400°C. There are a very large number of dyes. The following are representative of dyes selected by the US as satisfactory agents for producing burning type colored smokes:

Yellow: Auramine hydrochloride
Green: 1,4-Di-p-toluidinoanthraquinone with auramine hydrochloride
Red: 1-Methylanthraquinone
Blue: Not suitable for signaling because of excessive light scatter.

These dyes are mixed to the extent of about 50 percent with a fuel such as lactose (20 percent) and an oxidizer (30 percent) for which potassium chlorate is preferred. If the mixtures should still burn too hot (and thereby destroy the dye), sodium or potassium bicarbonate are added as cooling agents. Colored smoke compositions are usually used in a compressed state without a binder. A major concern at present is the reported carcinogenic nature of organic dyes and elaborate programs have been initiated for their destruction. In addition to the smoke grenades which function by burning, others produce smoke by volatization of the dye from a separate dye compartment. These dyes should preferably have melting points below 150°C and be stable in the vapor phase. The following are currently used dyes:

Orange: 1-(4-Phenylazo)-2-naphthol
Yellow: N, N-Dimethyl-p-phenylazoaniline
Blue: 1,4-Diamylaminoanthraqdinone

Mixtures of these dyes produce muddy colors of various hues. Lastly, dyes can be dispersed by explosive charges. These generate colored clouds (about 10 x 20m) which are formed instantaneously and which have a life expectancy, depending on environmental conditions, from 65 to 85 seconds, whereas aerial burning of the aforementioned burning type produces streamers about one meter across which last for about 57 to 120 seconds.

d. Tracers and Fumers. The principal small arms application of military pyrotechnics is in tracer munitions where they serve as incendiaries, spotters, and as fire control. Two types of tracers are used. The difference between the two types is the method of tracking. The more frequently used tracer uses the light produced by the burning tracer composition for tracking. Smoke tracers leave a trail of colored smoke for tracking. Red is the flame color most often employed in tracers. Red has a longer wavelength and so can penetrate haze, dust, and fog better than the other colors. A tracer may be directly ignited by the flame from a propellant charge or, as is the case in larger caliber shells, the ignition may be delayed to hide the position of a cannon. Table 10-4 lists several tracer and delay compositions.

Table 10-4. Typical Formulas for Igniter and Tracer Compositions

Ingredient (%)	Delay action igniter 1-136	Dim igniter 1-194	Daylight (bright) igniter 1-276	Red tracer R-257	Fumer R-284
Strontium peroxide	90	-	-	-	-
Magnesium	-	6	15	28	28
1-136 Igniter	-	94	-	-	-
Calcium resinate	10	-	-	4	-
Barium peroxide	-	-	83	-	-
Zinc stearate	-	-	1	-	-
Toluidine red (identifier)	-	-	1	-	-
Strontium nitrate	-	-	-	40	55
Strontium oxalate	-	-	-	8	-
Potassium perchlorate	-	-	-	20	-
Polyvinyl chloride	-	-	-	-	17

Compositions have also been developed for electro-optical devices. These compositions consist of calcium resinate, barium and strontium peroxides, and magnesium carbonate. The mechanism of tracer reactions is a complex one; the burning rate and brightness decrease with altitude but increase with increasing spin rate of the bullet. Smoke tracer compositions contain about 70 percent strontium peroxide, 10 percent calcium resinate, 10 percent catechol, and 10 percent smoke dye. Methylaminoanthraquinone is the dye used in red smoke and auramine is used for greenish-yellow smoke. A fumer, or gas generating tracer, uses the gaseous products of the burning tracer to fill the vacuum created behind the moving projectile. This increases range and decreases time of flight.

e. Incendiaries. Two types of incendiaries are commonly used. The traditional type is a bomb containing a flammable material. These materials include thermite (a mixture of aluminum and rust), phosphorus, and napalm. In addition, the case of the bomb may be constructed of a material such as magnesium that will burn at a high temperature once ignited. The burning material may be explosively scattered over a wide area. The more recently developed type of incendiary uses metals which produce pyrophoric, or burning, fragments. Three properties have been identified as important for metals which are suitable for use as incendiaries. The heat of formation of the oxide must be greater than 400 kilojoules per mole of oxygen consumed. The ratio of the oxide volume to metal volume must be greater than one.

The metal must also have electrons in the conduction band. Formation of an intermetallic compound that reduces the number of electrons in the conduction band reduces the pyrophoricity of the compound. Table 10-5 lists the properties of metals considered suitable for incendiary use.

Table 10-5. Properties of Pyrophoric Metals

Metal	Heat of oxide formation (per mole of oxygen)	Oxide volume/ metal volume	Electronic structure
U	-536	3.10	$6d^1\ 7s^1$
Th	-587	1.36	$6d^2\ 7s^2$
Zr	-512	1.55	$4d^2\ 5s^2$
Hf	-577	1.62	$5d^2\ 6s^2$
Ce	-486	1.23	$5d^0\ 6s^2$
La	-641	1.11	$5d^1\ 6s^2$
Pr	-621	1.12	$5d^0\ 6s^2$
Nd	-617	1.12	$5d^0\ 6s^2$
Sm	-431	1.06	$5d^0\ 6s^2$
Y	-427	1.44	$4d^1\ 5s^2$
Ti	-426	1.78	$3d^2\ 4s^2$

For straight incendiary applications the sponge form of these metals is used because this form provides a large surface area. Metals which are used in this application include zirconium, titanium, and mischmetal. Polytetraflouroethylene can be used as an oxidizing agent. The heat of the reaction for several metals is shown in table 10-6. The numerical values given are strongly affected by the stoichiometry and the effective density of the reactants.

Table 10-6. Maximum Volumetric Heats of Reaction for Metals Reacting with Fluorocarbons

Metal	Product	Kilojoules per cubic centimeter
Be	BeF2	-24.0
La	LaF3	-21.0
U	UF3	-19.8
Mg	MgF2	-19.8
Hf	HfF3	-19.0
U	UF4	-18.9
Zr	ZrF3	-18.6
Zr	ZrF4	-18.6
Hf	HfF4	-18.2
Ti	TiF3	-17.0
Ti	FiF4	-14.6

Depleted uranium is used extensively in pyrotechnics which have armor piercing capabilities. Depleted uranium deficient in the more radioactive isotope U235, is the waste product of the uranium enrichment process. The depleted uranium is formed into projectiles that can penetrate armor because of their high density and mechanical properties. The impact of the projectile causes the uranium to form many pyrophoric fragments which can ignite fuel and munition items.

f. Delays and Fuses. Delay compositions are mixtures of oxidants and powdered metals which produce very little gas during combustion. Work on delay systems continues because the existing delay mixtures do not store well and scale-up is not as flexible and as precise as is desired. A basic reason is that gasless delay mixtures are not truly gasless because gaseous reagents are present in the flame front or in the ignition mix. The gaseous reagents contribute to the pressure in the column so that the burn time is not strictly a linear function of the column length. This phenomenon has been called the anticipatory effect. Table 10-7 lists the most important delay compositions in use at the present time.

Table 10-7. Delay Compositions

Mixture	Illustrative Composition		Burn time range centimeters per second	Temperature coefficient %/ºK	Delay time change on storage in seconds per year per centimeter
D-16	Mn PbCrO4 BaCrO4	29% 26% 45%	0.8 - 5.4 (obturated)	0.17	0.02
T-10	B BaCrO4	3 - 15% 97 - 85%	0.23 - 0.32 (obturated)	0.23 - 0.32	0.15 - 0.38
Zr-Ni Delays	Ni-Zr BaCrO4 KC104 Up to 10°/o	26% 60% 14% CeO2	0.8 for 70/30 Zr-Ni, 4.6 for 30/70 Zr-Ni, 7.8 with Ce02 (vented)	0.16	0.06
Tungsten-Viton	W BaCr04 KC104 Diatomaceous earth Viton	30% 55% 10% 4% 1%	Approximately 0.8 - 6.2 (vented)	0.1	Not known, not suitable for storage in high humidity
UMNOL Tungsten Delay	W BaCr04 KC104 Diatomatceous earth	30% 55% 10% 50/o	0.04 - 16 Up to 24 with CaF2 (vented)	0.1	Sensitive to moisture

The delay time change, or aging, is caused by the corrosion of the metallic fuels. The rate of corrosion is increased by the presence of moisture. In general the burn time of the delay is adjusted within stated limits by controlling the percentage of fuel in the composition. The chromate oxidizers may be carcinogenic.

g. Photoflash Compositions. Photoflash compositions are the single most hazardous class of pyrotechnic mixtures. The particle size of the ingredients is so small that burning resembles an explosion. The various photoflash devices are similar, differing principally in size and the amount of delay. When fired, each photoflash cartridge, after one, two, or four seconds, produces a flash having a peak intensity of approximately 50 million candela with a total output of five million candela seconds, whereas photoflash bombs generate above 5 x 109 candela. The most commonly used fuels include aluminum and magnesium. The most commonly used oxidizers include barium nitrate and potassium perchlorate. While atomized magnesium gives higher intensities in consolidated compositions, atomized aluminum performs better in loose compositions than do other fuels. Potassium perchlorate produces the highest heat of reaction with atomized aluminum. The output is highest for fuel rich compositions and alkaline earth nitrates which are far superior to alkali metal nitrates. Constant aluminum particle sizes of 22±+8 micrometers resulted in optimum efficiency at all altitudes. At high altitudes zirconium performs better. Photoflash compositions containing halfnium and potassium perchlorate possess greater luminous efficiency on a volume basis than do other formulations. Zirconium, for example, when burned in oxygen has an average color temperature of 4,883°K compared with 5,235°K for halfnium at peak intensity. In pyrotechnic flash units, substitution of aluminum with halfnium and titanium produced comparable peak output, but inferior output when zirconium and cesium were substituted.

h. Igniters and Initiators. Black powder is used extensively as an igniter for artillery propellant charges. Table 10-8 lists various black powder compositions used by the United States.

Table 10-8. Black Powders Used in Pyrotechnics

Components (%)	Formulas 146	147	148
Potassium nitrate	74.0	70	-
Sodium nitrate	-	-	72
Charcoal	15.6	-	16
Coal (semibituminous)	-	14	-
Sulfur	10.4	16	12

A small amount of graphite is added as a glazing during the finishing process. The burning rate of black powder is dependent on the granulation of the ingredients and the grain size. The burning can be described as low order detonation. Coarse unpressed powders which are confined have approximate burning rates of 170 meters per second. Fine, unpressed, confined powders have burning rates of approximately 950 meters per second. A newer formulation of black powder called pyrodex consists of six percent sulfur, 10 percent charcoal, 83 percent potassium nitrate, and one percent calcium carbonate. This mixture has an ignition temperature above 260°C compared with 125°C for regular black powder. Other mixtures called either first fire, ignition mixtures, or starters are used. The names are somewhat misleading. The mixtures are intermediates between the primary igniter and main charge. Table 10-9 lists some of the numerous formulations of this type mixture.

Table 10-9. Ignition Mixtures.

Components, %	Formulas 60	68	69	164	165	173	174	175	176	177	178	179	180	181	182	183	184
Aluminum (powdered)	-	-	-	-	-	-	-	-	-	40.0	-	-	-	-	35.0	20.0	-
Ammonium dichromate	-	-	-	-	10.5	-	-	-	-	-	-	-	-	-	-	-	-
Asphaltum	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	-	-	-
Barium chromate	-	-	-	-	-	-	-	-	-	-	-	-	90.0	-	-	-	-
Barium peroxide	-	-	-	-	-	78.0	80.5	4.0	79.0	31.0	91.0	-	-	-	-	-	-
Boron (amorphous)	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	23.7
Calcium resinate	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	-	-
Charcoal	-	-	-	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Diatomaceous earth (See also superfloss)	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe_2O_3(Red)	49	-	-	-	5.0	-	-	-	-	-	-	50.0	-	25.0	-	-	-
Fe_3O_4(Black)	-	-	-	-	-	-	-	-	-	29.0	-	-	-	-	-	-	-
Potassium nitrate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70.7
Potassium perchlorate	-	-	-	-	74.0	-	-	-	-	-	-	-	-	-	64.0	63.0	-
Laminac	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6
Magnesium (powdered)	-	-	-	-	-	-	-	-	-	-	9.0	-	-	-	-	-	-
Sodium nitrate	-	-	-	47.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrocellulose	-	-	-	-	10.5	-	-	-	-	-	-	-	-	-	-	-	-
Parlon (chlorinated rubber)	-	-	-	-	-	-	-	-	5.6	-	-	-	-	-	-	-	-
PbO_2	-	80	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb_3O_4	-	-	-	-	-	20.0	17.5	25.0	14.0	-	-	-	-	-	-	-	-
Sr peroxide	-	-	-	-	-	-	-	70.0	-	-	-	-	-	-	-	-	-
Sugar	-	-	-	47.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Superfloss	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-
Titanium	-	-	-	-	-	-	-	-	-	-	-	32.5	-	-	-	13.0	-
Toluidine red toner	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-
Vegetable oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-
Vistanex (polyisobutylene)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.0	-
Zinc Stearate	-	-	-	-	-	-	-	1.0	0.9	-	-	-	-	-	-	-	-
Zirconium	41	20	40	-	-	-	-	-	-	-	-	17.5	-	65.0	-	-	-

i. Simulator Compositions. Simulator compositions are used to simulate the functioning of ammunition items during training exercises. Simulators can harmlessly duplicate the effects of air bursts, boobytraps, ground bursts, gunflashes, and hand grenades. Simulators which must produce a loud noise may use black powder or such compositions as a mixture of aluminum powder, potassium perchlorate, and barium nitrate. These simulators also produce white smoke. Grey or black smoke can be produced by carbon rich compounds such as naphthalene which do not oxidize completely. Simulators can also contain colored smoke compositions for marking the positions of certain types of hits such as chemical or incendiary projectile impact. Some simulators contain a pyrotechnic whistle. Picric acid and such other organic acids as gallic, salicylic, and benzoic having the same characteristic odor, are the major ingredients in pyrotechnic whistles. Combinations of these acids with potassium chlorate, perchlorate, or nitrate, compressed in short tubes, emit a shrill whistling sound of varying pitch when ignited. Size, especially length of the tube in which the composition is pressed, determines pitch.

10-2. Manufacturing of Pyrotechnics.

a. *Storage.* Care must be exercised in the storage and handling of pyrotechnics and pyrotechnic ingredients. Small quantities of contaminants can cause changes in stability and burning rates which lead to inconsistency in performance.

b. *Grinding.* The particle size of the ingredients is extremely important in pyrotechnic compositions. Three methods are used to grind the particles to the proper size. One method is with a hammer mill. A hammer mill consists of a series of hammers which rotate at high speeds. The impact of the hammers grinds the material. Some heat sensitive material such as waxes or resins may be cooled with dry ice or liquid nitrogen before being processed by the hammer mill. Materials which cannot be ground safely in a hammer mill are ground in a ball mill. In the ball mill the sample is placed in a sealed drum with a large number of steel, brass, or ceramic balls. The drum is rotated. The tumbling of the balls grinds the material. The third method of grinding, an attrition mill, is used to further reduce the size of the particles of powder. In the attrition mill a stream of high velocity air is used to accellerate particles of the powder. The collisions of the particles with one another break them down further.

c. *Classification.* After grinding, the powders are classified by size. For powders above 44 microns, sieves are used. For powders below 44 microns, cyclones are used. Cyclones are funnel shaped chambers into which the powder is fed. An air current is maintained which centrifugially separates the powders by size. The coarser materials are forced to the wall of the container.

d. *Weighing*. To obtain the proper performance from a pyrotechnic composition accurate weighing is necessary.

e. *Blending*. Two methods are used for the blending of pyrotechnic compositions, dry and wet. The dry method is used for insensitive material. Passing the ingredients through sieves is used for small quantity production. A ball mill which uses rubber balls is used for larger quantities. Wet mixing is accomplished with the ingredients suspended in a liquid. This method is used to blend more sensitive materials.

f. *Granulation*. In order to ensure the pyrotechnic composition is sufficiently fluid after blending, the mixture is forced manually through a sieve. An alternate method is to press the composition into a cake and then granulate the cake.

g. *Loading.* Loading pyrotechnic compositions is accomplished by means of a press. Special tools support the element into which the composition is being loaded. Multiple layers of different types of composition are loaded by multiple pressing operations.

h. *Drying.* Drying is accomplished by subjecting the ingredients to 105° to 110°C for two to four hours. Vacuum drying may be necessary to further reduce moisture content.

i. *Assembly*. The pyrotechnic item is now ready for assembly into the end item. Care should be taken to prevent exposure to moisture and ensure the pyrotechnic item is properly supported for transportation.

10-3. Testing. The different types of tests used in the process of developing pyrotechnic ammunition are described in this paragraph.

a. *Kinds of Tests.*

(1) Development tests. Development tests are performed by the designing agency to ensure that component subassemblies or complete ammunition function in the manner for which they were designed. These tests evaluate the latest efforts of the designer and may be repeated until successful results are obtained. The ammunition is subjected to a series of tests that serve to determine that the device is safe and reliable, and to ascertain readiness for field testing and use. Part of the task of planning an ammunition development project is to specify the type of test, the order of execution, and other testing details. Development tests are usually made in the laboratory or developer's testing facility, and need not include all of the parts of the complete device.

(2) Evaluation. Evaluation tests are made to assess the usefulness of a pyrotechnic system. These tests expose the characteristics of the hardware to observation by personnel experienced with pyrotechnic applications. An evaluation of a flare launcher, for example, includes describing the launcher, evaluating projected altitude, illumination duration, effects of water soaking, day and night range functioning, ability to penetrate foliage, and comparing .38 and .45 caliber cartridges. Recommendations are made on the basis of these tests.

(3) Service tests. Service tests are intended to determine the suitability of hardware for use by the military under field conditions. They compare the hardware with requirements set down in the documents for the device being tested. The tests are always carried out on the complete device under field conditions. Acceptance tests are one form of service test.

(4) Surveillance tests. Surveillance tests are made on specific lots of ammunition taken from storage to determine if changes are needed in components to provide satisfactory operation as well as to determine the degree of deterioration of the original lot. Such tests should include adequate sampling of the lot to assure true representation and isolation of troublesome components, and adequate tests to assure satisfactory performance of renovated ammunition. Tests of this type will salvage lots of satisfactory ammunition whenever possible.

(5) Malfunction tests. Malfunction tests are carried out whenever failures have occurred. The rationale and planning for such tests is usually the responsibility of the investigator. Special tests are applied to pinpoint the cause of failure and recommend corrective action.

(6) NATO tests. NATO tests are prescribed for safety and environmental survival of all ammunition components planned for use by NATO countries. Engineering design tests are listed for airborne devices for both packaged and unpackaged stores.

b. *Light*.

(1) General. Light producers can be tested by use of human observers, simple electrical light detectors, or complex arrays of light detectors coupled to recording instruments and to computers for analysis of light intensity and spectal content as a function of time. Observers are used in many field situations that are difficult to assess by instrumentation systems and, therefore, play an important role in the ultimate testing of pyrotechnic light producers. Many test programs, for quality assurance of existing candles and the development of new types, are performed indoors at large military installations which have flare tunnels. A few instrumented outdoor sites are available to evaluate the light output of complete pyrotechnic ammunition under a semblance of field conditions.

(2) Laboratory tests. The candle of a pyrotechnic device is usually tested as a separate component in development, production, and quality control efforts. Candles with outputs of up to 106 candelas are commonly tested in areas equipped to contain the burning candle safely and to measure the emitted light under controlled conditions. These areas consist of a fireplace or hearth and a light tunnel. These facilities are well suited for making comparative measurements of burning time and candlepower of flares, but caution is required in relating values obtained to those obtained in different tunnels, outdoor facilities, and actual end item conditions. Large variations can easily occur depending on the test system, test procedures, and the inherent variability of the flares. If the candle is tested with the burning surface upward, for instance, the reading will be greater than if the burning surface is pointed downward. This is due to the differences in flame shape and smoke pattern. The practical difficulties in measuring true candlepower of pyrotechnic flames makes reference to the specification under which the test was performed necessary when quoting the candela for a particular device. Nevertheless, measurements made under comparable conditions are valuable to rate light output and to maintain quality standards. The light output of small arms tracer projectiles is measured in a spinner that is capable of rotating the projectile at up to 130,000 rpm's. Light intensity measurements in tunnels are affected by the following variables.

(a) Usually, large volumes of smoke issue from the test flare. The smoke can reflect light or obscure the flame depending upon the motion of the smoke. Blowers and dampers are used to adjust the wind velocity to maintain control of this variable.

(b) Power density radiated by the flare is a variable. The flare is not truly an isoentropic source, as assumed in calculations, because flux is not radiated uniformly over the entire burning surface. Radiation from the cylindrical sides may be twice that from end on. Measurements in tunnels are usually made from the side of the flare.

(c) The area of the flare in the field of the photocell is a variable. Intensity readings will be incorrect if the field of the optical system includes only a portion of the flame produced by the flare. The entire flame produced by the flare should be in the field of view of the photocell, and any light reflected from the smoke in the vicinity of the burning flare should be kept to a minimum.

(d) The reflectivity of the background is a variable. Background reflections can produce particularly large errors in measurements of light output. Apparent increases of 40 percent have occurred because of reflections from the tunnel floor. This condition is corrected by restricting the view of the measuring instrument to that portion of the flare producing the light.

(e) The accuracy of the spectral correlation and intensity calibration is a variable. Spectral correction conforming to the response of the International Commission of Illumination and intensity calibration with standard sources for the test equipment are required.

(3) Field tests. The flame size and volume of smoke produced by some flares is too great for indoor tests. Such flares are tested outdoors at test sites that are relatively flat, open areas approximately 120 meters (400 feet) in diameter and that have a means of suspending the flare at least 24 meters (80 feet) above the center of a plane containing the photocells. Often the most practical method of evaluating light effects is visual observation supplemented with photography. This is particularly true of small arms tracers.

(4) Color measurement. The color of light producing illuminants is assessed by visual observation of flare burning or by the use of instruments that can dissect the light into characteristic colors or wavelengths. Quantitative spectral data allows the engineer to observe dilution of a desired color by unwanted colors, thus enabling corrections to be made. These procedures may also be used for quality control during production. A flare radiometer consists of a number (10 is used in the Picatinny Arsenal apparatus) of interface filters, which cover the visible spectral region. The filters are chosen to have a uniform spectral response at a precisely chosen peak wavelength. Photocells and associated circuits are positioned behind the filters. The output of the photocells can be digitized and interfaced directly with a computer. Correction for human eye response can be made automatically. Candlepower can be computed by integration of the luminous intensity over the wavelength range of interest. Dominant wavelength and purity are determined by multiplying the radiant energy distribution by the three color distributions of the International Commission of Illumination, wavelength by wavelength. Chromaticity coordinates are calculated from the integrals under the three product curves and plotted in a chromaticity diagram to determine dominant wavelength and purity.

c. *Smoke.*

(1) General. In early stages of development, when gross effects are sought, much is gained by simple visual observation of the smoke produced. Visual observation is usually followed by still and motion photography to make better estimates of volume and color. In the case of screening smokes, quantitative measurements of the obscuring power can be made by the attenuation of light by the smoke. Signalling smokes have four properties of importance to the military: color, visibility, duration, and volume. Since instability is one of the main features of the smoke cloud, the ability to persist is usually judged by comparison with smoke from a control that is being burned simultaneously within close proximity of the test smoke generator. Care must be taken to observe that the two independent plumes are observed under similar atmospheric conditions.

(2) Laboratory tests. The test volume of the equipment used to measure smoke production may vary from a few cubic feet to several thousand cubic feet. The test chambers usually provide a means of physically manipulating the sample under test including parts or fittings for air, smoke, and exhaust; and an optical system for obscuration measurements. The screening values of smokes are determined by a figure of merit known as the total obscuring power *(TOP)* which is the area in square feet that can be obscured by a pound of smoke formulation. *TOP* can be measured directly by positioning a target in a smoke chamber until the target is just obscured. *TOP* can also be determined by measuring the attenuation of a light beam through a fixed distance of smoke. The intensity of the light as a function of incident intensity is given by the equation:

$$I=I_o \exp(eCL) \quad (10\text{-}1)$$

where I is the observed light intensity, I_0 is the intensity with no smoke present, C is the concentration of the smoke in pounds per cubic foot, L is the path. length in feet, and e is the scattering or extinction coefficient in feet squared per pound. *TOP* is defined by the equation:

$$TOP = \frac{I}{C_t L_t}$$

where C_t is the concentration of smoke required for obscuration in pounds per cubic feet and L_t is the fixed distance between the lamp and photocell in feet. The concentration of smoke, C, from equation 10-1 is related to the concentration in equation 10-2 by the relationship:

$$C = YC_t \qquad (10\text{-}3)$$

where Y is the yield or the ratio of the weight of aerosol produced to the unit weight of the smoke producing composition. Combining equations 10-1, 10-2, and 10-3 yields:

$$TOP = \frac{Y}{\ln(I_t/I_o)} \qquad (10\text{-}4)$$

where I_t is the transmitted light intensity under obscuration. The value of 0.0125 has been adopted by some researchers for the ratio I_t/I_o based on physiological studies of the discriminating capacity of human vision. Equation 10-4 yields:

$$TOP = \frac{\ln(/I_o)}{(\ln 0.0125)CL_t} \qquad (10\text{-}5)$$

For fixed chambers and weights of smoke producing compounds equation 10-5 becomes:

$$TOP = K \log(I_t/I_o) \qquad (10\text{-}6)$$

Equation 10-6 is valid if the smoke is dilute so that particle coalescence is minimal.

(3) Field tests. In the field, observers are often used in the assessment of smoke producing ammunition. A number of observers are commonly used in order to obtain statistically significant results. Any person with serious visual defects is eliminated, usually by tests made immediately before the observation. Color blindness is of particular concern when testing colored smokes. Observers are sometimes supplied with binoculars during smoke tests. They compare performance with controls having well known characteristics. Wind tends to produce both good and bad effects in smoke production and use. In outdoor tests, wind speed and direction are normally recorded. Wind may aid in distributing the smoke for screening purposes. If the smoke is produced continuously, wind often helps to pinpoint a marked area by observing the origin of the plume. On the other hand, the wind may scatter the smoke. In testing field ready smoke producers, each sample is numbered. The ignition time and burning time of each sample is recorded. Comments concerning out of the ordinary conditions, such as excessive sparking on ignition, flame-ups while burning, and fuze failures are also recorded.

(4) Photographic techniques. Smoke plumes can be studied with time exposure photography. Exposure times of several minutes can be used to study the diffusion of smoke into the atmosphere. Time exposure during the daylight requires either an extremely slow film, a very small aperature, or the use of very dense filters. If these conditions cannot be attained, the dispersion photographs can be made under twilight conditions.

d. *Heat.* Incendiary devices are normally evaluated in terms of their ability to inflict specific damage against specifically defined targets such as burning a hole through a metal plate. The burning time is another of the parameters that is commonly measured. Several techniques, such as photography and the use of spectrometers and radiometers, have been tried to improve these testing methods. Photography with infrared film with appropriate filters can provide an effective means of evaluating the temperature distribution over the surface of a large flame, provided the fuel is relatively homogeneous and the observation path is relatively homogeneous. The film should be calibrated with a black body source of infrared and the calibration film and recording film should be processed identically. Small arms incendiary rounds can be evaluated by firing against an aluminum plate and recording the flash photographically. The photographs are compared to photographs of acceptable rounds. The following factors should be measured or assessed qualitatively in tests of flame producers. Quantitative methods have not been devised to measure all the factors:

(1) Fuel dissemination in terms of "blob" size, spectral and spacial distribution.
(2) Percentage of the fuel that ignited.
(3) The adhesiveness of fuel "blobs" to different surfaces as a function of the type of surface, "blob" velocity, and altitude.

(4) Fuel spread and runoff during burning.

(5) Oxygen depletion or contamination.

(6) Heating of the air in the vicinity of the target.

(7) Damage capability as a function of target type.

e. *Gas-Operated Devices*. Pyrotechnic gas generators may be designed to produce various quantities of gas at various rates and temperatures and under a variety of loading conditions. Gas operated devices are tested under conditions nearly the same as those anticipated during use. Special test fixtures may be required, but normally a closed bomb with a fixed volume approximately equal to the volume in the actual application will suffice. Some test fixtures provide for expansion of the chamber with a moveable member as pressure is applied from the pyrotechnic device. This type of test measures the ability of the pyrotechnic device to do some minimum amount of work. Both the pressure and the displacement of the moveable member are measured. Piezoelectric sensors are used for pressure measurement. Capacitance, inductance, or resistance sensors are used for displacement measurement. Piston, bellows, and dimple motors can be actuated by the expanding gases. These motors are evaluated using force measuring transducers or by working them against springs. Testing includes measuring the time from the initiation impulse and the time from the start to the end of motion. The gas producer and the pressure bomb must be properly sealed. Copper washers are normally used for this purpose.

10-4. Analysis of Protechnic Compositions. The following methods are used at the discretion of the researcher to yield the particular data sought.

a. *Differential Thermal Analysis*. The same method used in the analysis of explosives and discussed in Chapter 5 is used for pyrotechnic compositions. DTA can give qualitative information about the composition of a mixture. The presence of an endotherm or exotherm, which is characteristic to a particular compound, indicates the presence of the compound in the mixture. The ignition temperature of the mixture can be determined. DTA can also be used to determine the purity of the sample since impurities greatly affect the melting point. A sharp endotherm at the melting point indicates higher purity than a broad endotherm at a level slightly lower than the melting point.

b. *Thermogravimetry.* The same method used in the analysis of explosives and discussed in Chapter 5 is used for pyrotechnic compositions. Either method may be used on pyrotechnic compositions: the weight can be monitored as the temperature is programed to rise linearly with time or the weight can be monitored at a constant temperature. The former is the preferred method.

c. *Infrared Spectroscopy*. This method is discussed in Chapter 13.

d. *Thermal Conductimetric Analysis*. In thermal conductimetric analysis, the electrical conductance of the material under test is measured as a function of temperature. The variation in conductivity is caused by such events as crystalline transitions which change the crystal lattice in such a way that the energy required to cause electrons to go from the bound state into the conduction band is altered.

e. *Electrothermal Analysis*. Electrothermal analysis consists of measuring two quantities as a function of temperature. The capacitance of the sample, which changes during a crystalline transition between two stable forms, is measured. The dissipation factor is also measured. The dissipation factor is the heat loss from an AC signal applied to the crystal. A transition also causes the dissipation loss to increase during the change between the two stable states.

f. *Classical Chemical Analysis*.

(1) To test for positive ions, add 300 milligrams of the sample to be tested to water and mix. Filter the slurry and divide the filtered solution into two parts. To one part of the solution add a drop of a saturated sodium sulfate solution. Barium or strontium will come out of the solution as a white precipitate. A flame test on a platinum wire, using the part of the solution that was not treated with sodium sulfate, identifies barium or strontium. A green flame is produced by barium salts and a red flame is produced by strontium salts. To find the quantities of barium and strontium, add sodium sulfate until no more precipitation is formed. Filter and weigh the precipitate. The untreated aqueous solution may be flame tested for sodium and potassium. A yellow and violet flame is produced respectively, although the potassium test is diffcult. NH4 can be detected by an ammonia smell after the solution has been made basic with sodium hydroxide.

(2) To test for anions, the barium and strontium ions must be removed by precipitation with an excess of sodium sulfate.

(a) To test for ClO_3, add one milliliter of the test solution to one milliliter of a solution that was prepared from 20 grams of aniline hydrochloride and 50 milliliters of hydrochloric acid. The presence of the ion is indicated by a pink violet or dark blue color.

(b) To test for NO_3, add two milliliters of the test solution to two milliliters of a solution that was prepared from 25 grams of $FeSO_4$ in 100 milliliters of distilled water and 25 milliliters of concentrated sulfuric acid. Hold the test tube at a slight angle and add one milliliter of concentrated sulfuric acid to the wall of the test tube. Manipulate the test tube to cause the drop to slide down the wall and into the solution. The drop of sulfuric acid will sink to the bottom. A brown color at the interface between the sulfuric acid and water indicates the presence of the nitrate.

(c) To test for ClO_4, first prepare a solution of 40 milliliters of 10 percent aqueous $CuSO_4$, 19 milliliters pyridine, and 50 milliliters of distilled water. This solution must be stored in a tightly stoppered bottle to avoid breathing the pyridine vapors. Add two milliliters of this solution to 3 milliliters of the solution under test. A precipitate of blue or white crystals indicates the presence of the perchlorate ion. If no precipitation forms in a few minutes, scratch the bottom of the test tube with a glass rod to try to induce crystallization.

(d) To determine the amount of the chlorate quantitatively, add an excess of $NaHSO_3$, and then precipitate AgCl by adding an excess of silver nitrate solution. Filter and weigh the precipitate. One gram of precipitate corresponds to 0.855 grams of $KC10_2$ in the mixture.

(e) To determine the amount of the perchlorate quantitatively, use tetraphenylphosphonium chloride to precipitate the tetraphenylphosphonium salt.

(f) To determine the amount of NO_3, the chlorate and perchlorate must be removed from the solution. Then nitron is used to form a precipitate. Nitron is a standard reagent with the formula $C_{20}H_{16}N_4$ and a molecular weight of 312.38.

(3) In the original test mixture the materials which did not dissolve in water are most likely either metals, sulfur, or charcoal. Magnesium will cause the evolution of bubbles of hydrogen gas if five percent acetic acid is added. Aluminum will not. Aluminum will evolve hydrogen in five percent hydrochloric acid or five percent sodium hydroxide. To test for iron, dissolve in dilute hydrochloric acid or nitric acid and add potassium ferrocyanide. A blue color indicates iron. To test for sulfur, dissolve in carbon disulfide or pyridine and dry the solvent. The characteristic yellow color indicates sulfur. Charcoal will produce an orange flame in the flame test.

10-5. Sensitivity.

a. *Impact.* This test is performed on any of the various impact sensitivity devices.

b. *Friction.* This test is performed on the pendulum friction device.

c. *Hygroscopicity.* In this test a weighed sample of the material is subjected to air at a specified temperature and relative humidity. The weight gain is noted.

d. *Sensitivity to Heat*. Three methods are used to measure sensitivity to heat.

(1) In the first method, a sample of the material is contained in a blasting cap and immersed in molten metal bath. The temperature of the bath is controlled so that a reaction occurs in five seconds.

(2) In the second method, isothermal heating, a sample of the material is subjected to a preselected temperature for an extended period. This method determines the induction period of the material at a specified temperature.

(3) In the third method, adiabatic heating, a sample is placed in an oven or furnace and heated at a slow rate. A thermocouple monitors the temperature at the sample. When an exothermic reaction starts, the temperature of the furnace is adjusted so no heat is gained or lost by the sample. The temperature at which the reaction accelerates to deflagration is called the autoignition or deflagration temperature.

e. *Electrostatic Discharge*. The standard electrostatic discharge sensitivity device described in Chapter 5 is used for this test.

f. *Compatibility*. This test is performed by mixing a sample of the pyrotechnic composite with another material and subjecting the mixture to the 120°C vacuum stability test for 40 hours.

CHAPTER 11
FOREIGN ENERGETIC MATERIALS

11-1. Introduction. This chapter reflects the currently available, unclassified information on foreign energetic materials. Security restrictions may, in some cases, date the material presented. Generally, foreign energetic materials are the same as those used by the United States although the composition of some of the composites varies.

11-2. French Energetic Materials. No information is presented on priming compositions or initiating explosives. The French for fulminating explosives such as mercury fulminate is explosifs fulminants. Table 11-1 lists some of the secondary explosives used by the French.

Table 11-1. French Secondary Explosives

English	French
TNT	Trotyl
Pyroxylin	Pyroxyline, collodion
Pyrocellulose	Coton-Poudre (CP)
Guncotton	Coton-Poudre (CP)
Nitroglycerin	Nitroglycerine
Nitrostarch	Nitrate d' amidon
PETN	Penthrite
TEGN	Dinitrate de triethyleneglycol
HMX	Octogene, cyclotetramethylenetetrnitramin
RDX	Hexogene, T4, cyclotrimethylene-trinitramine
Picric acid	Melinite

The following explosives are also used by the French:

a. *Explosif Amylace*. These are the amide explosives. An inorganic amide explosive, also called ammonobase, is a compound in which one hydrogen is replaced by a metal. Metallic amides are prepared by precipitation from liquid ammonia solutions by the action of potassium amide, KNH_2. Potassium amide is also referred to as potassamide. An organic amide contains the monovalent radical $-CO.NH_2$. Organic amides are nonexplosive unless nitrated and are not considered here. The metallic amides include:

(1) Auric imidoamide, $Au(:NH)NH_2$ or $HN:Au.NH_2$, is an extremely explosive and sensitive powder. The compound does not explode when wet and so is stored under water. Storage at 100°C for several hours causes auric imidoamide to become so sensitive that handling without an explosion is virtually impossible.

(2) Cadmium amide, $Cd(NH_3)$, is a white powder which explodes upon rapid heating. The salt can be prepared by treating cadmium iodide or KCd cyanide with a solution of potassamide in liquid ammonia. When heated to 180°C in vacuo, cadmium amide loses ammonia leaving cadmium nitride, Cd_3N_2, a black, amorphous powder that explodes when brought in contact with water.

(3) Potassium amide, KNH_2, is not used as an explosive but is used as an intermediate in the preparation of other explosive amides. The normal method of preparation is to add a small amount of platinum black to a solution of liquid ammonia and metallic potassium. Without the platinum, the reaction takes weeks or months.

(4) Silver amide, $AgNH_2$, is a white precipitate which darkens and shrinks in volume on exposure to air. The compound can be prepared by mixing a solution of potassamide with silver nitrate or iodide in liquid NH followed by washing by decantation and careful drying. This compound is extremely sensitive and can shatter test tubes and tear holes in several layers of towels wrapped around the tube for the protection of the operator.

(5) Sodium amide, $NaNH_2$, consists of white crystals with a melting point of 206.4°C. The compound dissolves in liquid NH_3 and is vigorously hydrolyzed by water. Preparation is by means of metallic sodium dissolved in ammonia, the reaction is catalyzed by iron wire.

b. *Explosifs Antigrisouteux*. These are French industrial explosives used in coal mines. Under prescribed conditions these do not ignite mixtures of methane, air, and coal dust. Some standard compositions are:

Components	N no 7	N no 9	N no 62
Ammonium nitrate (%)	76.0	48.2	12.0
Dinitronaphthalene (%)	7.0	-	-
TNT (%)	-	9.15	-
PETN (%)	-	-	23.0
Wood flour (%)	2.0	1.65	-
Sodium chloride (%)	15.0	41.0	65.0

c. *Explosifs Chlorates*. These explosives are also known as chlorate cheddites or chlorate streetites. The chlorate cheddites may be subdivided into nongelatin and gelatin types. The nongelatin type cheddites are in the form of soft grains which are white or yellow in color unless they have been artifically colored with an oil soluble dye in order to distinguish one type from another. They are readily compressible and, in order to obtain the full explosive power, their density should be carefully controlled. If the density is low, the maximum power is not developed but if the density is very high detonation is difficult. These explosives are relatively insensitive to shock and friction at room temperature and, when unconfined, burn more or less rapidly without any tendency to explode even when fired in large masses. Heating at 120°C for an appreciable period causes no decomposition. But at 200°C the oil in cheddite decomposes, part of the nitrocompound volatilizes, and the whole mass darkens. Heating of cheddites in small quantities to 250° to 265°C causes deflagration. Densities of compressed materials average 1.3 to 1.4, power (by Trauzl test) is slightly less than that of TNT, but brisance is only 30 to 50 percent of TNT due to the low detonation velocity, 2,300 to 3,200 meters per second. The rate of detonation depends not only on composition but also on density. The rate of detonation increases as the density increases up to a certain optimum density, but then the rate decreases very rapidly. For example, one of the cheddites developed the rate 2,283 meters per second at a density of 1.07 grams per cubic centimeter which increased to 2,901 meters per second at a density of 1.17 grams per cubic centimeter but dropped to 2,451 meters per second at a density of 1.14 grams per cubic centimeter and failed to detonate at density of 1.5 grams per cubic centimeter. None of the chlorate cheddites can contain any ammonium salt because double decomposition might take place with the formation of dangerous ammonium chloride. Cheddites containing potassium or sodium perchlorates are more stable and less reactive than those containing potassium or sodium chlorate. Ammonium perchlorate may also be used, provided chlorates are absent. Sodium chlorate is more hygroscopic than potassium chlorate, but is more economical and contains more oxygen per unit weight. The gelatin type cheddites are plastic type explosives which do not harden in storage. These explosives are not very powerful but their brisance is superior to any ammonium nitrate explosive. Tables 11-2 and 11-3 give the composition of some of the most current French cheddites.

Table 11-2. French Chlorate Cheddites

Composition and some properties	55 -CSE -1948	58 -CSE -1948	gelatin cheddite n° 18
Sodium chlorate (%)	74	74	74.0
DNT (liquid) (%)	23	23	19.0
Sawdust (%)	-	3	-
Cork flour (%)	3	-	-
NG (%)	-	-	5.5
Collodion cotton (%)	-	-	1.5
Density, grams per centimeter	-	-	2.0
Power (picric acid 100%)	93	89	83

Table 11-3. French Perchlorate Cheddites

Composition	I	II	III	Sevranites n°1	Sevranites n°2
Ammonium perchlorate (%)	82	50	88 - 9	31	42
Sodium nitrate (%)	-	30	-	-	-
DNT (%)	13	15	-	-	-
Castor oil (%)	5	5	-	-	-
Paraffin (%)	-	-	12 - 10	-	-
Collodion cotton (%)	-	-	-	-	-
PETN (%)	-	-	-	48	42
Plasticizer (%)	-	-	-	18	16
Aluminum powder (%)	-	-	-	3	-

d. *Explosifs Couche.* These are explosives with temperatures of explosion of below 1,500°C which are permitted for use in coal layers of fiery coal mines. For example, Grisou naphthalite couche contains 95 percent amtmonium nitrate and 5 percent trinitronaphthalene, while Grisou dynamite couche contains 12 percent nitroglycerin, 0.5 percent collodion cotton, and 87.5 percent ammonium nitrate. Sodium chloride is also used in couche to reduce the explosion temperature.

e. *Explosifs CSE*. These are a series of explosives developed at the laboratory of the Commission des Substances Explosives (CSE). The explosifs chlorates are actually CSE explosives. Other examples include: 63-CSE-1949 which contains 67 percent ammonium nitrate, 12 percent 20/80 pentolite, and 21 percent aluminum powder; 68-CSE-1949 which contains 20 percent ammonium nitrate, 20 percent PETN, 1.5 percent dinitronapthalene, and 58.5 percent sodium chloride; 123-CSE-1948 which contains 17 percent ammonium nitrate, 23 percent PETN, and 60 percent sodium chloride; and 133-CSE-1948 which contains 22 percent ammonium nitrate, 20 percent PETN, 3 percent TNT, and 55 percent sodium chloride. These are used in fiery coal mines. Table 11-4 shows some of the silicon CSE explosives.

Table 11-4. CSE Silicon Explosives

Composition and properties	Designation of explosive			
	n°78 CSE-1950	n°88 CSE-1950	Nn°O	Nn°31
Ammonium nitrate (%)	79.0	82.0	78.7	78.5
Silicon (pulverized) (%)	5.5	7.4	-	-
Aluminum (granular) (%)	-	-	-	9.2
TNT (%)	-	10.6	21.3	-
Pentolite (20/80) (%)	15.5	-	-	12.3
Density, grams per centimeter	1.40	1.24	1.40	1.40
Velocity of detonation meters/second	4,700	4,000	4,460	4,150

Some of the following plastic explosives were developed by the CSE. 33-CSE-1951 contains 75 percent RDX, 21 percent nitroglycerin, and 4 percent nitropolystyrene. 34-CSE-1951 contains 88 percent ammonium nitrate and 12 percent RDX. 36-CSE-1951 contains 82 percent RDX and a solution of 40 percent polystyrene in liquid DNT. This explosive has a velocity of detonation of 7,520 meters per second. 37-CSE-1951 contains 85 percent ammonium nitrate and 15 percent nitropolystyrene. 38-CSE-1951 contains 72.25 percent ammonium nitrate, 12.75 percent nitropolystyrene, and 15 percent sodium chloride.

f. *Explosif D*. This explosive contains 85 percent RDX and 15 percent TNT.

g. *Explosifs et Poudres*. These explosives and propellants include mixtures of combustibles such as nitroguanidine, hexanitrodiphenylamine (HNDPhA), and 9-oxo-2,4,5,7-tetranitrothiodiphenylamine with oxidizers such as nitrates, chlorates, or perchlorates. A mixture of 53 percent nitroguanidine and 47 percent ammonium perchlorate and a mixture of 56 percent nitroguanidine and 44 percent potassium nitrate possess high temperatures of deflagration and are suitable for use in weapons operating at high temperatures or for oil seismic prospecting at great depth.

h. *Exploslfs Roche*. These explosives, with temperatures of explosion between 1,5000C and 1 ,9000C, are permitted for use in rock layers of fiery coal mines. Grisou dynamite roche contains 29 percent nitroglycerin, 1 percent collodion cotton, and 70 percent ammonium nitrate. Grisou dynamite roche salpetree contains 29 percent nitroglycerin, 1 percent collodion cotton, 5 percent potassium nitrate and 65 percent ammonium nitrate.

11-3. German Energetic Materials. Table 11-5 lists some of the secondary explosives used by the Germans.

Table 11-5. German Secondary Explosives

English	German
DEGN	Diathylenglykol-dinitrat
Pyroxylin	Kollodiumwolle
Pyrocellulose	Schiessbaumwolle
Guncotton	Schiessbaumwolle, schiesswolle
Nitroglycerin	Nitroglyzerin
Nitrostarch	Nitrostaerke, staerkenitrat
PETN	Peutrit, niperyth, nitropenta (NP)
TEGN	Triglykoldinitrat
EDDN	Diamin
Nitroguanidine	Gudol
TNT	Fp 02

Table 11-5. German Secondary Explosives (Cont)

11-4. Italian Energetic Materials. Italian explosives are listed in table 11-6.

Table 11-6. Italian Explosives

English	Italian
Lead azide	Azotidrato di piombo, acido di piombo
Lead styphnate	Stifnato di piombo
Mercury fulminate	Fulminato-di mercurio
Tetracene	Guanilnitrosoammina, tetrazene
DEGN	Nitrodiglicole, nitroeterolo, dinitrodietilenglicol
Collodion cotton (11.2 to 12.3% N)	Cotone collodio
Pyrocellulose (12.5 to 12.7% N)	Pirocollodio
Guncotton (13.2 to 13.4% N)	Fulmicotoneo cotone fulminante
Nitroglycerin	Nitroglicerina
PETN	Pentrite, tetranitrato di penaeritrite
TMETN	Metriolo (nitrometriolo), nitropentaglicerina
HMX	Ciclotetrametilentetranitro-ammia, octogene, HMX
RDX	Ciclonite, ciclotrimetilentrinitro-ammia
Nitroguanidine	Nitroguanidina
Tetryl	Tetrile
Ammonium picrate	Picrato ammonico, picrato di ammonio
TNT	Tritolo

The following explosives are used by the Italians:

a. *Afocite*. Afocite is a blasting explosive composition in two formulations. One formulation is 58 percent to 62 percent ammonium nitrate, 28 percent to 31 percent potassium nitrate, 7 percent to 9 percent carbon, and 2 to 3 percent sulfur. The other formulation is 58 to 62 percent ammonium nitrate, 31 percent to 38 percent potassium nitrate, 3.5 percent to 4.5 percent charcoal, 2 percent to 3 percent sulfur, and 1.5 percent moisture.

b. *Amatolo*. These are the amatols. The most popular mixture is tipo 60/40, which has 60 percent ammonium nitrate and 40 percent TNT. Other compositions used are tipo 80/20 and tipo 90/10.

c. *Ammonaftite*. This is a mining explosive containing 76.7 percent ammonium nitrate, 15 percent nitroglycerin, 0.3 percent collodion cotton, 0.3 percent grain flour, and 0.5 percent yellow ocher.

d. *Ammonal*. These are mixtures containing various percentages of ammonium nitrate, aluminum, and TNT.

e. *Ammonite No. 1*. This is a blasting explosive consisting of 88 percent ammonium nitrate, 3 percent DNT, 3 percent nitroglycerin, 5 percent vegetable flour, and 1 percent diphenylamine.

f. *Antigrison*. These are permissible explosives. Autigrison N.O contains 80.57 percent ammonium nitrate, 6.36 percent dinitronaphthalene, and 13.02 percent ammonium chloride. Autigrison N.2 contains 81.49 percent ammonium nitrate, 11.11 percent dinitronaphthalene, and 7.4 percent ammonium chloride. Autigrison N.3 contains 82 percent ammonium nitrate, 5 percent trinitronaphthalene, and 13 percent ammonium chloride.

g. *Autonile*. There are two explosive mixtures of ammonium nitrate and TNT. In one, used in quarries, the oxygen content is 5.9 percent. The other, used in tunnels, has an oxygen content of 3.08 percent.

h. *BM*. These are a series of mining explosives.

(1) BM.1. per galleria is a grey powder consisting of TNT, ammonium nitrate, and thermite.

(2) BM.as. per uso a cielo aperto is a reddish powder consisting of ammonium nitrate, cyclic aliphatic compounds, and metallic powders.

(3) BM.ac. per uso a cielo aperto is a brownish yellow powder containing ammonium nitrate and TNT.

(4) BM.57. per uso a cielo aperto is a greyish black powder based on ammonium nitrate.

(5) Super BM. per galleria is a green powder which is slightly plastic. The powder contains aromatic nitrocompounds with organic nitrates and plasticizers.

(6) BM.a2 is a brown powder containing ammonium nitrate, TNT, and thermite.

(7) Super BM. cava is a grey powder.

(8) BM.2. per galleria is a grey powder containing an inorganic nitrate, organic nitrocompounds, and aluminum powder.

(9) Carlsoniti are perchlorate based explosives such as one formulation that contains 85 percent $KClO_4$ and 15 percent vaseline and another that contains 88 percent $KClO_4$ and 12 percent dinitrobenzene.

i. *Italian Dynamites*. Italian dynamites are divided into two groups, those with inert bases and those with active bases.

(1) The inert base dynamites are:

(a) Tipo I which consists of 70 to 75 percent nitroglycerin and 25 to 30 percent kieselguhr.

(b) Tipo II which consists of 50 percent nitroglycerin and kieselguhr.

(c) Dinamite nera (black dynamite) which consists of 45 to 55 percent nitroglycerin and 45 to 55 percent coke.

(d) Dinamite al carbonie di legno (charcoal dynamite) which consists of 90 percent nitroglycerin and 10 percent charcoal.

(e) Dinamite rossa (red dynamite) contains 68 percent nitroglycerin and 32 percent tripoli.

(f) Wetter-dinamite (permissible dynamite) contains 35 to 40 percent nitroglycerin, 10 to 14 percent kieselguhr, and 32 to 50 percent magnesium sulfate.

(2) The active base dynamites are:

(a) Gelatinagomma (or gelatina esplodente) which is a blasting gelatin with the composition of 92 to 93 percent nitroglycerin and 7 to 8 percent collodion cotton.

(b) Gelatina esplosiva da guerra which is a military blasting gelatin with the composition 86.4 percent nitroglycerin, 9.6 percent collodion cotton, and 4 percent camphor.

(c) Gelatina dinamite is a gelatin dynamite containing 67 to 86 percent nitroglycerin, 3 to 5.5 percent collodion cotton, 5 to 25 percent potassium nitrate, and 2 to 10 percent woodflour.

(d) Ammon dinamite (gelatina 65 percent) contains 63 percent nitroglycerin, 2 percent collodion cotton, 30 percent ammonium nitrate, and 5 percent woodflour.

(e) Gelatina dinamite incongelabile o antigelo, a nonfreezing gelatin dynamite, contains 20 to 25 percent nitroglycerin, 1 to 2 percent collodion cotton, 8 to 12 percent nitrotoluenes, 25 to 60 percent of a mixture that contains sodium nitrate and ammonium nitrate, and 1 to 8 percent cereal flour.

(f) Gelatina 40 percent contains 40 percent nitroglycerin, 10 percent drip oil, 44 percent sodium nitrate, and 6 percent cereal flour. The drip oil contains liquid DNT's and is a biproduct of TNT manufacture.

(g) Ammon-gelatina I contains 40 percent nitroglycerin which has been gelatinized with collodion cotton, 45 percent ammonium nitrate, 5 percent sodium nitrate, and 10 percent woodflour.

(h) Ammon-gelatina II contains 20 percent nitroglycerin gelatinized with collodion cotton, 75 percent ammonium nitrate, and 5 percent woodflour.

(i) Dinamite No. 1, non-gelatinizzate contains 70 to 74 percent nitroglycerin and 30 to 26 percent woodflour.

(j) Dinamite No. 2, non-gelatinizzate contains 35 to 48 percent sodium nitrate and/or lead nitrate (52 to 39 percent) with 12 to 17 percent cereal flour.

(k) Table 11-7 lists the composition of some more nitroglycerin based dynamites. GDI, GDII, CD2, GDM, GEO, gomma A, and gomma B are the most frequently used.

j. *Diamon.* This is an explosive which consists of 69 percent ammonium nitrate, 8 percent KC104, 20 percent TNT, and 3 percent aluminum.

k. *Diamon 1B.* This is a mining explosive containing ammonium nitrate, TNT, woodmeal, 3 to 6 percent nitroglycerin, and some other ingredients.

l. *Esplosivi Da Mina*. Mining explosives are listed in tables 11-8 and 11-9.

Table 11-7. Esplosivi Da Mina Gelatinosi Con Nitroglicerina
(Mining Explosives with Nitroglycerin)

Composition (%) and some properties	1 GDII	2 GD2	3	4 GDI	5 GDIM	6 GEOM	7	8	9 GEO	Gomma B	Gomma A	GDM
Nitroglycerin	43.2	48.3	7.0	60.0	38.0	57.0	71.0	40.75	77.5	82.5	92	38.0
Collodion cotton	2.3	2.7	0.8	3.5	2.3	3.5	5.0	1.5	5.0	5.5	8	2.3
Ammonium nitrate	-	-	-	-	50.9	29.0	-	17.0	-	-	-	50.4
Ammonium perchlorate	-	-	44.0	-	-	-	-	-	-	-	-	-
Woodflour	7.0	5.8	1.0	5.2	-	3.5	5.0	-	5.0	3.0	-	-
Dinitrotoluene	-	-	10.0	-	-	-	-	-	-	-	-	-
Trinitrotoluene	-	-	5.0	-	-	-	-	-	-	-	-	-
Sodium nitrate	45.5	42.7	32.2	30.5	6.0	7.0	-	-	12.0	8.5	-	6.0
Potassium nitrate	-	-	-	-	-	-	18.5	-	-	-	-	-
Calcium silicide												
Oil	-	-	-	-	2.0	-	-	-	-	-	-	2.5
PETN	-	-	-	-	-	-	-	40.75	-	-	-	-
Ocher, red (hematite)	-	-	-	0.3	0.5	-	0.5	-	-	-	-	0.5
Ocher, yellow (limonite)	1.0	-	-	-	-	-	-	-	-	-	-	-
Sodium carbonate	1.0	0.5	-	0.5	-	-	-	-	0.5	0.5	-	-
Calcium carbonate	-	-	-	-	0.3	-	added 0.3	-	-	-	-	0.3
Trauzl test, cc	340	355	430	440	475	500	505	525	540	560	630	475
Gap test, cm	14	15	6	20	21	23	26	25	29	30	35	-
Velocity of detonation, m/sec	5,000	5,200	4,700	6,000	5,900	5,400	5,900	7,000	6,700	6,900	7,200	-

Table 11-8. Esplosivi Da Mina Polverulenti Con Nitroglicerina (Pulverulent Mining Explosives with Nitroglycerin)

Composition (%) and some properties	1	2	3	4	5	6	7	8	9	10	11	12
Nitroglycerin	14.0	11.0	10.0	4.0	4.0	8.0	12.4	12.76	4.0	12.0	11.7	9.0
Dinitrotoluene	-	-	-	1.5	-	0.5	0.3	-	-	-	-	-
Trinitrotoluene	-	-	-	-	-	-	-	-	10.0	0.3	-	20.0
Collodion cotton	0.3	-	0.25	1.5	0.1	0.5	0.3	0.24	-	-	0.3	0.3
Woodflour	-	6.0	-	-	-	-	-	-	-	-	-	-
Cereal flour	-	-	-	-	-	5.0	-	-	-	3.0		
Ammonium picrate	65.7	51.0	89.75	82.0	89.4	81.0	79.0	83.0	76.0	77.7	76.0	70.7
Sodium nitrate	-	-	-	-	-	-	-	-	-	-	-	-
Potassium nitrate	-	-	-	-	-	-	-	-	-	-	-	-
Dinitronaphthalene	-	10.0	-	-	-	-	8.0	4.0	10.0	-	10.0	-
Potassium perchlorate	-	-	-	-	-	-	-	-	-	-	-	-
Sodium chloride	20.0	22.0	-	11.0	-	-	-	-	-	-	-	-
T4 (RDX)	-	-	-	-	6.5	-	-	-	-	-	-	-
Oil	-	-	-	-	-	-	-	-	-	2.0	2.0	-
Calcium silicide		-	-	-	-	5.0	-	-	-	5.0		
Trauzl test, cc	270	265	300	305	320	375	390	390	400	420	430	450
Gap test, cm	2	5	20	3	12	6	3	4	11	1	1	6
Velocity of detonation, m/sec	2,120	2,300	2,038	1,710	2,500	3,200	2,715	3,200	2,348	2,960	2,350	2,912

Table 11-9. Esplosivi Da Mina Polverulenti Senza Nitroglicerina (Pulverulent Mining Explosives Without Nitroglycerin)

Composition (%) and some properties	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ammonium nitrate	85.5	77.0	40.0	78.0	82.0	80.0	79.5	70.0	84.5	90.0	-	79.0	70.0	63.0
Dinitronaphthalene	-	-	-	-	-	-	-	5.0	10.0	-	-	-	-	-
Dinitrotoluene	-	-	-	-	1.0	-	-	-	-	-	-	-	-	-
Trinitrotoluene	4.5	15.0	-	16.0	14.0	20.0	10.0	10.0	-	8.0	90.0	-	-	-
Ammonium perchlorate	-	-	25.0	-	-	-	-	-	-	-	-	-	-	-
Potassium perchlorate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium nitrate	-	-	29.0	-	-	-	-	-	-	-	-	-	-	-
Woodflour	10.0	6.5	4.0	-	3.0	-	2.5	-	-	2.0	-	1.0	-	3.0
Oil	-	-	2.0	-	-	-	-	-	-	-	-	-	-	-
Paraffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sodium nitrate	-	-	-	4.5	-	-	8.0	15.0	-	-	-	-	-	13.0
Potassium bichromate	-	-	-	-	-	-	-	-	4.5	-	-	-	-	-
Carbon (pulverized)	-	1.5	-	-	-	-	-	-	1.0	-	-	-	-	-
Charcoal (pulverized)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PETN or RDX	-	-	-	-	-	-	-	-	-	-	10.0	20.0	30.0	21.0
Calcium carbonate	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-
Ocher (hematite)	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-
Trauzl test, cc	330	330	350	400	420	430	450	360	395	375	400	425	450	480
Gap test, cm	1	2	3	6	6	7	7	2	3	1	4	5	3	6
Velocity of detonation, m/sec	1,900	2,300	2,400	3,600	3,700	4,300	3,500	1,600	3,100	2,300	7,000	2,850	2,100	3,000

m. *Esplosivi di Primari*. These are primary explosives. Mercury fulminate has been replaced by lead azide and lead styphnate.

n. *Esplosivi di Rinforzo*. These are the booster explosives. RDX, PETN, and tetryl are used.

o. *Esplosivi di Scoppio*. These are the high explosives. Those which have been used include amatolo, ammonal, HMX, PETN, pentolite, RDX, tetryl, TNT, tritolital (60 percent TNT, 20 percent RDX, and 20 percent aluminum), and tritolite (60 percent RDX, 39 percent TNT, 1 percent beeswax). The following bursting explosives have been patented in Italy for military use. One is a cast explosive that is prepared by incorporating 75 percent RDX or PETN with 25 percent nitroisobulylglycerol. Another explosive consists of 5 to 65 percent RDX or PETN with 30 to 90 percent TNT, and 5 to 30 percent powdered metals such as silicon, boron, magnesium, copper, iron, aluminum, orzinc. RDX and 8 to 14 percent castor oil pressed in the form of beads has also been patented. A process for directly producing a cast explosive has also been patented. Molds or bomb bodies are loaded with a granulated mixture of nitrocellulose and a high explosive followed by the addition of a solvent containing a nitrated ester, a stabilizer, a plasticizer, and sometimes an accelerating agent. The final composition of the explosive may be 5 to 36 percent nitrocellulose, 33 to 40 percent nitrate ester, 20 to 60 percent high explosive, 1.5 to 2.5 percent plasticizer, 0.5 to 0.6 percent stabilizer, and 0.4 to 0.5 percent accelerating agent. The granulated composition is obtained by mixing the nitrocellulose, the high explosive, a plasticizer (diethylphthalate), and a stabilizer (centralite) with a nitrocellulose solvent (acetone). The paste obtained is impregnated in the mold with nitroglycerin and the diethylphthalate in a solvent, centrifuged, and gelled at 50°C. Another explosive consists of RDX or PETN with high density nitrates such as lead nitrate, barium nitrate, and zinc stearate.

p. *Esplosivo Plastico*. This is a plastic explosive suitable for military use which consists of 85 to 89 percent RDX, 10 to 12 percent petrolatum, 0.5 to 2 percent plastic binder, and 0.5 to 1 percent glycerophthalic acid. An aluminized version consists of 64 to 75 percent RDX, 10 to 12 percent petrolatum, 10 to 25 percent aluminum powder, 0.5 to 2 percent plastic binder, and 0.5 to 1 percent glycerophthalic acid.

q. *Esplosivo S20*. This is a military explosive which contains 79 percent ammonium nitrate, 20 percent TNT, and 1 percent woodflour.

r. *Grisou Dinamite*. This is a permissible explosive containing 88 percent ammonium nitrate, 10 percent nitroglycerin, 0.5 percent collodion cotton, and 1.5 percent woodflour.

s. *Grisounite*. This explosive contains 95.5 percent ammonium nitrate and 4.5 percent trinitronaphthalene.

t. *Grisounite Gomma*. This explosive contains 70 percent ammonium nitrate, 29.5 percent nitroglycerin, and 0.5 percent collodion cotton.

u. *Grisounite Roccia* or Rock Grisounite. This explosive contains 91.5 percent ammonium nitrate and 8.5 percent trinitronaphthalene.

v. *Hexocire*. This is a mixture of RDX and beeswax.

w. *Hexocire-Aluminum*. This explosive is a mixture of 80 percent RDX, 5 percent beeswax, and 15 percent aluminum.

x. *Hexaliti*. These are mixtures of RDX and aluminum in various proportions.

y. *MAT*. This is the Italian name for picratol.

z. *Miscela C or PE*. A plastic explosive consisting of RDX and a plasticizer. Miscela C_2, which is waterproof, consists of RDX, collodion cotton, and a plasticizer. Miscela C_3 consists of RDX, tetryl, collodion cotton, and a plasticizer. Miscela C_4 consists of 91 percent RDX with polyisobutylene and other ingredients.

aa. *NA OC*. This is the Italian name for ANFO explosives.

bb. *Nitroglicol*. This explosive is also called dinitroglicol in Italian. The English term is ethyleneglycol dinitrate. This compound is used in many countries as an antifreeze in nitroglycerin mixtures such as dynamite.

cc. *Nobelite Galleria*. This is a mining explosive consisting of 37 percent nitrocellulose, 34 percent $KClO_4$, 24 percent $NaNO_3$, 3 percent DNT, and 2 percent mineral oil. The temperature of explosion is 2,800°C. At about 130°C the explosive burns in air.

dd. *Nougat or MST*. This is an amatol type explosive used as a shell filler which consists of 49 percent ammonium nitrate, 44 percent TNT, and 7 percent dinitronaphthalene.

ee. *NTP*. This is a military explosive that consists of 77 percent ammonium nitrate, 20 percent RDX, and 3 percent paraffin.

ff. *Oxiliquite*. This is one of the liquid air explosives prepared in situ by pouring liquid air or liquid oxygen into a mixture of three parts carbon impregnated with two parts petroleum.

gg. *Oxilite*. This is another liquid air or oxygen explosive prepared in situ. The fuel in this explosive is fossil flour that has been impregnated with petroleum.

hh. *Pentritolo*. In Italian this is also called pentrol. The English name is pentolite.

ii. *PNP Esplosivo*. This is an explosive used for press loaded projectiles that consists of 20 percent PETN, 77 percent ammonium nitrate, and 3 percent wax.

jj. *Polvere FB.* There are 860 and 960 calorie types which contain 32 and 31 percent nitroglycerin, 57 and 61 percent nitrocellulose (12 percent nitrogen content), 9 and 5.5 percent butylphthalate, and 2 and 2.5 percent centralite. Both are used in rapid fire cannons.

kk. *Polvere FC*. There are 860 and 960 calorie types which contain 28 and 32 percent nitroglycerin, 64 and 62.5 percent nitrocellulose (12 percent nitrogen content), 4 and 3.5 percent centralite, and 1 and 0.5 percent vaseline. Both are used in rapid fire cannons.

ll. *Polvere NAC*. There are 860 and 960 calorie types which contain 27 and 32 percent nitroglycerin, 66 and 63 percent nitroacetylcellulose (11.2 percent nitrogen content), 7 and 4 percent centralite, and 0 and 1 percent DPhA. Both are used as cannon propellants.

mm. *Polvere Nera*. Italian for black powder.

nn. *Polvere al Nitrodiglical*. There are 860 and 730 calorie types which contain 68 and 27 percent DEGN, 30 and 63.5 percent nitroacetylcellulose, 0 and 5 percent acetylcellulose, and 2 and 4.5 percent centralite.

oo. *Polvere al Nitrometriolo*. These are propellants with TMETN. M4, M6, and M8 have compositions of 55.5, 57.5, and 59 percent TMETN; 40, 36, and 33 percent nitrocellulose; 2.5, 4.5, and 5.9 percent acetylmetriol; 2, 2, and 2.5 percent centralite.

pp. *Polveri da Lancio Senza Fumo*. These are the smokeless propellants. These are divided into single based propellants with a volatile solvent, double based propellants with nitroglycerin, double-base propellants without a volatile solvent, double-base propellants with a volatile solvent, and propellants with several components.

qq. *T_4 Plastico*. Two mixtures are known. One has 89 percent RDX and 11 percent vaseline and the other has 78.5 percent RDX, 17.5 percent DEGN (which contains 0.3 to 0.4 percent collodion cotton), and 3 percent vaseline.

rr. *Tetranitroauilina*. This is an explosive used in crystal form in some detonators.

ss. *Tetritol*. Italian for tetrytol.

tt. *Trinitrofloroglucinato di Piombo*. This compound is used in some initiating compositions in place of lead styphnate.

uu. *Umbrite*. There are two formulations of this explosive. Umbrite A contains 48.4 percent nitroguanidine, 37.3 percent ammonium nitrate, and 14.3 percent ferrosilicon. Umbrite B contains 45.1 percent nitroguanidine, 41.4 percent ammonium nitrate, and 13.5 percent ferrosilicon. Both are used as bursting charges in some projectiles.

11-5. Japanese Energetic Materials. Table 11-10 lists the Japanese explosives.

Table 11-10. Japanese Explosives

English	Japanese
Lead azide	Chikkgen, chikka namari
Mercury fulminate	Raiko, raisan
Nitrocellulose	Shokamen
Guncotton	Menyaku
Nitroglycerin	Nitoroguriserin
PETN	Shoeiyaku
RDX	Shouyaku, tanayaku
Tetryl	Meiayaku, sanshoki, mechira nitroamin
Ammonium picrate	Picurinsan ammonia
TNT	Chakatsuyaku, sanshokitoruoru
Ammonium nitrate	Ammon shosanen

The following limited data is available on the most currently used Japanese energetic material. Japan has no army but has a national self defense force. Energetic material research is done for this organization. Current developments and usage are along the lines of that in the western countries.

a. *Akatsuki*. This is an ammonium nitrate explosive containing 73 to 75 percent ammonium nitrate, 5 to 6 percent nitroglycerin gel, 3 to 5 percent cellulose, and 9 to 14 percent other ingredients. The explosive has a detonation velocity of 3,490 meters per second, an empirically determined detonation pressure of 42.3 kilobars, and a calculated detonation pressure of 33 kilobars.

b. *Ammonaru*. This is the Japanese name for ammonal.

c. *Kokushokuyaku*. This is the Japanese name for black powder.

d. *Chauyaku*. This is the Japanese name for 50/50 cyclotol.

e. *Dainamaito*. This is the Japanese name for dynamite. Japanese dynamites are based on nitroglycerin and are brown to buff in color. Some types of dynamites contain nitrocellulose and others contain diatomaceous earth. Some gelatin dynamites, the so-called faint smoke dynamites, contain borax or salt. Nonfreezing dynamites contain nitroglycol or dinitroglycerol. The Japanese also produce ammonium nitrate and semigelatin dynamites.

f. *Pentoriru*. This is the Japanese term for 50/50 pentolite.

g. *Shoanyaku*. These are a series of mining explosives which consist of the following:

(1) No. 1 contains 70 percent ammonium nitrate, 9 percent dinitronaphthalene, 1 percent woodmeal, and 20 percent salt.

(2) No. 2 contains 79 percent ammonium nitrate, 10 percent dinitronaphthalene, 1 percent saw-, dust, and 10 percent sodium chloride.

(3) No. 5 contains 64 percent ammonium nitrate, 12 percent TNT, 3 percent woodmeal, 1 percent wheat starch, and 13 percent sodium chloride.

(4) No. 7 contains 75 percent ammonium nitrate, 9 percent dinitronaphthalene, 1.5 percent TNT, 1.5 percent woodmeal, and 13 percent sodium chloride.

(5) Special contains 64 percent ammonium nitrate, 3 percent dinitronaphthalene, 7 percent TNT, 2 percent nitroguanidine, 2 percent sodium nitrate, 2 percent woodmeal, and 20 percent sodium chloride.

h. Shotoyaku. This is the Japanese name for amatol.

11-6. Russian Energetic Materials. Table 11-11 lists some explosives used by Russia.

Table 11-11. Russian Explosives

English	Russian
Lead azide	Azid svintsa
Lead styphnate	Stifnat svintsa, teneres
Tetracene	Tetratsin
Mercury fulminate	Gremoochaya rtoof
Guncotton	Khlopchatoboomazhnyi porokh
Pyroxylin (N>12%)	Kolloksilin, piroksilin
Pyrocellulose (11.5% <N <12%)	Piroksilin No. 2, pirokollodion
Nitroglycerin	Nitroglitserin
PETN	Ten
HMX	Oktoghen
RDX	Gheksoghen
Tetryl	Tetril
Ammonium picrate	Pikrat ammoniya, pikrinovokislyi ammonii
TNT	Toe, trotil
Ammonium nitrate	Ammoniynaya selitra

The following energetic materials are used by the Russians.

a. *A or AT.* This is the Russian abbreviation for amatol.

b. *A-IX-2.* This is an explosive mixture used as a projectile filler that contains 73 percent RDX, 23 percent aluminum powder, and 4 percent wax.

c. *Akvanity (Akvanites).* These are a series of industrial explosives.

(1) Plastic akvanites No. 2 and No. 16 have, in contrast to dynamites, a plasticizing base consisting of an aqueous solution of potassium nitrate thickened to a gel-like consistency in which ammonium nitrate and other constituents (such as combustibles) are also partially dissolved. Their liquid phase at normal temperature is about 20 to 25 percent, of which 5 to 7 percent is water.

(2) Slurry-type akvanite 3L (where L stands for l'yonshchiysya-pourable), uses as a base a thickened aqueous solution of ammonium nitrate making up 45 percent of the liquid phase. Other ingredients are as in dynamites. Akvanite 3L has a liquid-viscous consistency and therefore is suitable for charging descending blastholes and drillholes by the method of casting or by compression under water.

d. *Akvatoly (Akvatols*). These are industrial slurry explosives. Akvatol 65/35 contains granulated ammonium nitrate as an oxidizer, 27 to 30 percent TNT as a combustible and sensitizer, and 2.5 to 3.5 percent of the sodium salt of carboxymethylcellulose which is a thickening agent. Akvatol M-15 contains granulated ammonium nitrate, 12.5 to 13.2 percent coarse aluminum powder, 21 to 22 percent TNT, and 1.0 to 1.5 percent of the sodium salt of carboxymethyl cellulose. The water content of akvatol slurries must not exceed 13 to 25 percent by weight. In some cases the sodium carboxymethylcellulose can be replaced by other binding agents such as borax or polyacrylamide powder. Akvatols are usually prepared at plants and shipped in the form of anhydrous friable mixtures, packed in paper bags for the addition of water at the site of use. They can also be shipped in ready to use water filled slurries.

e. *Alyumatoly (Alumatols).* These are combinations of ammonium nitrate, TNT, and aluminum. Russian alumatols are granulated and waterproof. They are used in open cut work for breaking very hard rock.

f. *Alyumit No. 1.* This is a Russian commercial explosive that consists of 80 percent ammonium nitrate, 12 percent TNT, and 12 percent aluminum.

g. *Alyumotol*. This is a granulated melt of TNT and aluminum.

h. *Amatol*. This is the same as amatol in English.

i. *Ammoksily or Ammoxyly.* This is a nonpermissible mining explosive that consists of ammonium nitrate and trinitroxylene.

j. *Ammonaly*. This is the Russian name for ammonals.

k. *Ammonity (Ammonits).* Ammonits are ammonium nitrate mixtures of powdered structure in which TNT or other aromatic nitrocompounds are used as the explosive sensitizer and fuel. In grain or granulated form they are known as zernogranulity. The most current ammonits are:

(1) No. 6-ZhV and No. 7-ZhV are waterproof. The composition of the two is:

(2)

	No. 6	No. 7
Ammonium nitrate (%)	79	81.5
TNT (%)	21	16
Woodmeal (0/o)	-	2.5

(2) PZhV-20, AP-4ZhV, and AP-5ZhV are rock oriented. The composition of these is shown in table 11-12.

Table 11-12. Some Ammonits Formulations

	PZhV-20	AP-4ZhV	AP-5ZhV
Ammonium nitrate (%)	64	68	70
TNT (%)	16	17	18
Flame inhibitor (%)	20	15	12

(3) Ammonit skal'nyi No. 1 is used in the pressed state for blasting hard rocks in open or underground works.

(4) Ammonit V-3, shnekovannyi is used in flooded drill holes.

(5) No. 9-2hV and No. 10-ZhV are waterproof mixtures used for blasting soft or medium rocks. Their compositions are:

	No. 9	No. 10
Ammonium nitrate (%)	87	85
TNT (%)	5	8
Woodmeal (%)	8	7

(6) Ammonit sernyi No. 1 -ZhV, for use in sulfur mines, consists of 52 percent waterproof ammonium nitrate, 11.5 percent TNT, 1.5 percent woodmeal, 5 percent of a mixture of low freezing point nitroesters, and 30 percent flame inhibitor.

(7) Ammonit neftyanoy No. 3-ZhV, for use in mines with petroleum vapors, consists of 52.5 percent ammonium nitrate, 7 percent TNT, 1.5 percent calcium stearate, 30 percent flame inhibitors, 9 percent nitroesters, 0.3 percent collodion cotton, and 0.2 percent soda.

(8) Ammonit T-19, a safety explosive used in fiery mines, consists of 61 percent waterproof ammonium nitrate, 19 percent TNT, and 20 percent flame inhibitor.

(9) Shashki (demolition charges) skal'nago ammonita are compressed charges which serve as intermediate initiators for detonating nearly insensitive explosives.

l. Ammonit Predokhranitel'nyi. This is a safety commercial mine explosive which consists of 68 percent ammonium nitrate, 10 percent TNT, 2 percent powdered pine bark or oil cake, and 20 percent sodium chloride.

m. Ammonit V-3V Poroshke. This is a powdered explosive that contains 82 percent nonwaterproofed ammonium nitrate, 16.5 percent TNT, 1 percent asfal'tit, and 0.5 percent paraffin.

n. *Ammontol*. This is a castable high explosive mixture of 50 percent ammonium nitrate, 38 percent TNT, and 12 percent trinitroxylene that is used for loading some projectiles.

o. *Belity (Bellites).* These are extensively used commercial mining and blasting explosives. The following compositions are used; 35 percent ammonium nitrate and 65 percent dinitrobenzene, 87 percent ammonium nitrate and 13 percent dinitrobenzene, and 80 percent ammonium nitrate, 12 percent trinitroxylene, and 8 percent dinitrobenzene.

p. *Buryi Shokoladnyi Porokh*. These are the Russian brown powders. Brown powders are very similar to black powders except that the charcoal is brown because carbonization is only carried out to 70 to 75 percent. This is called buryi porokh, and is slower burning than black powder. A still slower brown powder is shokoladnyi porokh which has charcoal with a carbon content of 52 to 54 percent. Brown powders have been used in delay compositions and for time rings of fuses. The composition of some of these brown powders is listed in table 11-13.

Table 11-13. Russian Brown Powders

	No. 1	No. 2	No. 3
Brown coal (%)	4	6	7
Potassium nitrate (%)	59	67	76
Sulfur (%)	37	27	17
Velocity of burning (millimeters per second)	3	3.8	3.4

q. *Charnyi Porokh*. This is Russian for black powders which are also called pymnyi (smoke) porokh. Table 11-14 lists typical compositions.

Table 11-14. Russian Black Powders

	KNO_3	Sulfur	Charcoal
Military (%)	75	10	15
Fuse powder (%)	78	12	10
Blasting (%)	75 - 84	8 - 10	8 - 15
Blasting (%)	66.6	16.7	16.7
Tubular (%)	60 - 75	13 - 37	4 - 7
Sulfurless (%)	80	-	20
Sporting (%)	74 - 78	8 -10	14 - 16
Sporting (%)	80	8	12

r. *Detonity*. These are powdery, water resistant explosives used in hard rock blasting. Table 11-15 lists typical compositions.

Table 11-15. Detonity

Designation	6A	10A	15A - 10
Low freezing point organic nitrates (%)	6.0	10.0	14.7
Ammonium nitrate (water resistant ZhV) (%)	78.0	76.0	74.0
TNT (%)	11.0	8.0	-
Aluminum powder (%)	5.3	5.2	10.0
Calcium stearate (%)	0.7	0.7	1.0
Collodion cotton (%)	-	0.1	0.3
Soda (added above 100%)	0.2	0.2	0.2
Density, grams per cubic centimeter	1.1	1.1	1.1
Detonation velocity, meters per second	4,000	4,200	4,300

s. *Dinaftalit*. This is an explosive mixture that is used to fill shells and as a commercial blasting agent. Dinaftalit contains 88 percent ammonium nitrate, 11.6 percent dinitronaphthalene, and 0.4 percent paraffin.

t. *Dinitronaftalin*. This is Russian for dinitronaphthalene. This explosive is very weak and has an unsatisfactory oxygen balance. Dinitronaphthalene is not used alone, but is used as an ingredient in several composite explosives.

u. *Dinamity*. These are the Russian dynamites. The following types are used:

(1) Gremuchii studen' is a blasting gelatin that contains 87 to 93 percent nitroglycerin and 7 to 13 percent collodion cotton.

(2) Plasticheskii dinamit is a plastic dynamite that contains 62 to 83 percent nitroglycerin, 3 to 6 percent collodion cotton, 27 to 29 percent potassium or sodium nitrate, and 2 to 8 percent woodmeal.

(3) Grisutin contains 12 to 30 percent nitroglycerin gelatinized by collodion cotton and 70 to 88 percent ammonium nitrate with an absorbent such as limestone or sawdust.

(4) AM-8 contains 89 percent ammonium nitrate, 8 percent paraffin, and 3 percent mineral oil.

(5) AM-10 contains 87.7 percent ammonium nitrate, 10 percent paraffin, and 2.3 percent mineral oil.

v. *Grammonal*. These are powerful, granulated ammonals with an increased aluminum content. They are used in open pit blasting of hard rocks.

w. *Granulity*. These are granulated mining explosives. Typical compositions are given in table 11-16.

Table 11-16. Granulity

Components, granulites:	AC-8	AC-4	C-2	M
Ammonium nitrate, granulated (%)	89.0	91.8	92.8	94.5
Aluminum, powdered (%)	8.0	4.0	-	-
Woodmeal (%)	-	-	3.0	-
Mineral oil (%)	3.0	4.2	4.2	5.5
Detonation velocity, meters per second	3,000	2,600	2,400	2,500
Trauzl test value, cubic centimeters	410	390	320	320

x. *Igdanit*. This is an ammonium nitrate, fuel oil explosive that is prepared in situ just before use. Reported compositions vary from an ammonium nitrate composition of 94 to 97 percent.

y. *Mansit*. This is an explosive mixture that consists of 72 percent ammonium nitrate, 23 percent ammonium picrate, and 5 percent petroleum asphalt.

z. *Miporit*. This is an explosive used in gaseous mines that contains 65 percent waterproofed ammonium nitrate, 15 percent TNT, 18 percent flame inhibitor, and 2 percent foamed urea-formaldehyde resin.

aa. *Pobedit VP-4.* This is a permissible explosive used in fire damp mines that consists of 65.5 percent water resistant ammonium nitrate, 9.0 percent low freezing point organic nitrates such as nitroglycerin and nitroglycol, 12 percent TNT, 12 percent flame extinguisher, 1.5 percent woodmeal, 0.13 percent collodion cotton, 0.1 percent calcium stearate, and 0.1 percent soda.

bb. *Selectite No. 1 (Celektit No. 1).* This is a granulated, friable, water resistant ammonium nitrate explosive with 10 percent low freezing point nitrate esters.

cc. *Slurry Explosives*. These consist of ammonium nitrate in a thickened, water based suspension described in Chapter 8. Akvatols 65/35 and M-15 are considered slurry explosives.

dd. *Tetritoly*. This is Russian for tetrytol.

ee. *Uglenity*. These explosives, which are also called ooglenity, are coal mining explosives used in firedamp and dusty environments. They are ammonium nitrate based.

ff. *Zernogranoolity*. Waterproof ammonium nitrate explosives used for blasting rock of moderate hardness or hard rock on flooded faces.

11-7. Spanish Energetic Materials. Table 11-17 lists some of the explosives used by the Spanish.

Table 11-17. Spanish Explosives

English	Spanish
Lead azide	Azido de plomo, nitruro de plomo, plumbazida
Lead styphnate	Stifnato de plomo, trinitroresorcinato de plomo, triginato, tricinato
Tetracene	Tetraceno
Mercury fulminate	Fulminato de mercurio
Collodion cotton (N about 12%)	Algodon colodio, cotone colodio
Guncotton (N>12%)	Algodon fulminate, algodon polvora, fulmicoton
Nitroglycerin	Nitroglicerina aceite explosivo
PETN	Pentrita, nitropenta, nitropentaeritrita
RDX	Hexogeno, T4, exogeno, ciclonita
Tetryl	Tetralita, tetralo, tetranitrometilanilina
Ammonium picrate	Picrato amonico
TNT	Trilita, trotilo, tol, trinitrotolueno
Ammonium nitrate	Nitrato amonico

The following explosives are used by the Spanish.

a. *Amatolos*. This is Spanish for amatols.

b. *Amonales*. This is Spanish for ammonal.

c. *Amonitas*. These are explosives that contain from 50 to 100 percent ammonium nitrate, other nitrated products, and a small portion of other substances such as nitroglycerin, sawdust, and dichromates. Some explosives of this type are called explosivos favier, australita roburita, donarita, and perdita. Such mixtures are somewhat more sensitive to shock and friction and have a lower rate of detonation than other ammonium nitrate explosives. Their hygroscopicity and relative instability in prolonged storage are the principal disadvantages. They are used in mining operations and as main charges in some projectiles.

d. *Anagon*. This is an ammonal type explosive which contains 70 percent ammonium nitrate, 20 percent aluminum zinc alloy, and 10 percent charcoal.

e. *Antigrisu Explosives*. These are permissible explosives also known as explosivos de seguridad. Table 11-18 lists some compositions.

Table 11-18. Spanish Artigrisu Explosives

	No. 1	No. 2	No. 3
Ammonium nitrate (%)	80.6	80.9	82.0
Dinitronaphthalene (%)	6.4	11.7	
Ammonium chloride (%)	13.0	7.4	13.0
Trinitronaphthalene (%)	-	-	5.0

f. *Baratol*. These are high explosives that contain from 10 to 70 percent barium nitrate and TNT. They are used as bursting charges.

g. *Dinamitas*. This is Spanish for dynamite. These are considered industrial explosives. Spanish dynamites can be divided into two groups with variable composition.

(1) Dinamitas a base inerte are dynamites with an inert base. To this class belong the compositions containing 75, 50, or 30 percent nitroglycerin with kieselguhr. They are called number 1, 2, and 3 depending upon the nitroglycerin content. Dynamite 3 is the most popular type.

(2) Dinamitas a base activa are dynamites with an active base. These dynamites contain a combustible material or explosive material as the active base. The type of base material further divides these into classes.

(a) Dinamitas a base de nitratos use nitrates of ammonium, sodium, or potassium and a combustible such as carbon, sawdust, or flour.

(b) Dinamitas a base de chloratos use potassium or sodium chlorate in place of nitrates.

(c) Dinamitas gelatinas contain collodion cotton in sufficient proportion to gelatinize the nitroglycerin. Compositions that contain only nitroglycerin and collodion cotton are called goma. All others are called gelatina dinamita, nitrogelatina, or simply gelatina. If a dynamite less sensitive than gomas is desired, three to five percent camphor is added. Such compositions are called gelatinas explosivas de guerra (military gelatins).

h. *Dinamones*. Dinamones are permissible explosives similar to amonitas except that they do not contain aluminum or aromatic nitrocompounds.

i. *Donarita*. This is a mining explosive that contains 80 percent ammonium nitrate, 12 percent TNT, 4 percent gelatinized nitroglycerin, and 4 percent woodmeal.

j. *Explosivos cloratado*. This class of explosives contains 60 to 80 percent chlorates or perchlorates of sodium, potassium, or ammonium mixed with a combustible material such as carbon, sulfur, or aluminum. Organic combustibles such as vaseline, paraffin, or oils may also be used. These explosives are similar to ammonium nitrate but have a greater packing density and are more sensitive to impact. The explosives are used as a substitute for dynamite in mining operations.

k. *Explosivo Plastico "La Maranosa*." This plastic explosive consists of 85 percent RDX, 5.5 percent rubber, and 9.5 percent gelatinizing oil. The composite is of low sensitivity. At 200°C decomposition without explosion occurs but with the evolution of heavy nitrous fumes. A carbonaceous residue is left.

l. *Hexogeno Plastico*. These are also called plastex or PE. They correspond to American composition C. The explosive is prepared by coating granular RDX with 12 percent vaseline and other oily substances. The product is a yellow colored, plastic material which can be cut, perforated, and handled without extra precaution. Initiation is relatively easy with a blasting cap or various detonators. In extreme climates this explosive must be stored in protected areas. No casing is required in some demolition applications.

m. *Hexonitas*. These consist of 80 or 50 percent RDX and 20 or 50 percent nitroglycerin. The 50/50 composition can be further gelatinized and plasticized with some collodion cotton. A mixture of 50 percent RDX, 46 percent nitroglycerin, and 4 percent collodion cotton is called hexonita gelatinizada.

n. *Qxiliquita y Aire Liquido*. This is an explosive of liquid oxygen or liquid air with finely pulverized charcoal, cork dust, or other absorbent fuel.

o. *Polvoras Negras*. This is Spanish for black powder. Spanish black powders are divided into three groups.

(1) Polora de guerra, military black powder, contains 75 percent potassium nitrate, 12.5 percent charcoal, and 12.5 percent sulfur.

(2) Polvora de caza, sporting powder, contains 80 percent potassium nitrate, 11 percent charcoal, and 9 percent sulfur.

(3) Polvora de mina, blasting powder, contains 80 percent potassium nitrate, charcoal, and sulfur. The exact percentages of charcoal and sulfur are unknown.

p. *Tetritol*. This is Spanish for tetrytol. The Spanish use tetritol as a bursting charge and as a booster.

q. *Tonita*. This is a mixture of 68 percent barium nitrate, 13 percent dinitrobenzene, and 19 percent gun-cotton.

r. *Triplastita*. This is a gelatinized mixture of dinitrotoluene and guncotton that is less sensitive and more dense than TNT. Triplastita is used as a bursting charge in some ammunition.

s. *Tritolita*. This is Spanish for 50/50 cyclotol.

t. *Tritolital*. This explosive, also called torpex, is a castable mixture of 60 percent TNT, 20 percent RDX, and 20 percent aluminum. Tritolital is used as a bursting charge in depth charges and bombs.

11-8. Swedish Energetic Materials. As in the United States, Sweden's explosive industry consists of both privately owned and government facilities. Together they provide virtually all of the country's explosives plus significant amounts for export. The only items obtained abroad are initiating components such as primers and detonators. Sweden, however, is heavily dependent on imports for certain basic raw materials such as petroleum, coal, coke, cotton, sulfur, and others. Table 11-19 lists some of the explosives used by the Swedish.

Table 11-19. Swedish Explosives

English	Swedish
Lead azide	Blyazid, blyacid
Lead styphnate	Blystyfnat, blytrinitroresorcinat
Tetracene	Tetrazen
Mercury fulminate	Knallkvicksilver
Nitrocellulose	Nitrocellulosa
Pyroxylin	Piroxilina
Nitroglycerin	Nitroglycerin
RDX	Hexogen
PETN	Pentyl
Tetryl	Tetryl
TNT	Trotyl

a. *Ammongelatin Dynamit*. This is a gelatin dynamite. One formulation contains 71 percent nitroglycerin, 4 percent collodion cotton, 23 percent ammonium nitrate, and 2 percent charcoal. Another formulation contains 25 percent nitroglycerin, 1 percent collodion cotton, 62 percent ammonium nitrate, and 12 percent charcoal. The first of these two compositions is gelatinous while the second is crumbly and plastic. The basic formulations change by incorporating other explosives such as liquid DNT, TNT, trinitroxylene, nitrostarch, or nitroglycols. Such additives act not only as sensitizers for ammonium nitrate, but some also serve as antifreeze compounds.

b. *Ammoniakkrut*. This is an ammonium nitrate dynamite that consists of 80 percent ammonium nitrate and 20 percent charcoal. A modification of this mixture contains 80 percent ammonium nitrate, 12 percent nitroglycerin, and 8 percent charcoal. This modified mixture has been used somewhat but was found to be hygroscopic and exuded.

c. *Blastin*. This is a cheddite type safety explosive consisting of 63 percent ammonium perchlorate, 23 percent sodium nitrate, 8 percent DNT, and 6 percent paraffin. Blastin is reported to be 50 percent more powerful than dynamite and has been used extensively as a blasting and demolition explosive.

d. *Bonit*. This is Swedish for cyclotol. Three mixtures of RDX/TNT have been used: 50/50, 70/30, and 60/40.

e. *Bonocord*. This is a Swedish detonating cord which consists of a PETN core covered with braided cotton threads and protected by an outer coating of plastic which is based on polyvinyl chloride or polyethylene. Bonocord weighs 30 grams per meter and has an outer diameter of 5.5 millimeters. The quantity of PETN is 12 grams per meter. The detonation velocity is 6,000 to 7,000 meters per second. Bonocord is initiated with a number six exploder and is used for direct detonation of all types of explosive charges.

f. *Gelatinerad Dynamit*. These are gelatin dynamites. A typical composition is 62.5 percent nitroglycerin, 2.5 percent collodion cotton, 27 percent potassium nitrate, and 8 percent woodmeal.

g. *Hexotol*. This is the specific Swedish name for 60/40 cyclotol. Hexotol is considered a bonit and is used as a cast bursting charge in shells, land mines, demolition charges, boosters, and other military applications.

h. *Hexotonal*. This name is applied to several torpex type mixtures used as bursting charges. Some known compositions are listed in table 11-20.

Table 11-20. Hexotonal

	No. 1	No. 2	No. 3
RDX (%)	40	40	30
TNT (%)	44	40	50
Al (%)	15	15	20
Refined paraffin wax (%)	1	5	-
Wax added to mixture (%)	-	-	1
Carbon black added to mixture (%)	-	-	1.5

i. *Nobelit*. This is a permissible gelatin dynamite containing 28 percent nitroglycerin, 1 percent collodion cotton, 40 percent ammonium nitrate, 13.5 percent combustibles (such as flour, woodmeal, and dextrin), 17 percent sodium chloride, and 0.5 percent vegetable oil.

j. *Reolit A, B, C, D, or Eand Reomex A or B.* These are trade names for slurry blasting explosives.

k. *Seramin*. This is an ammonium nitrate dynamite consisting of 72.5 percent ammonium nitrate, 18 percent nitroglycerin, 8.7 percent sawdust or charcoal, and 0.8 percent benzene or creosote.

I. *Sprangdeg*. These are plastic explosives that usually contain RDX or PETN with a desensitizing oil and special plasticizers. One such explosive consists of 84 percent PETN and 16 percent mineral oil that is mixed by a special procedure. The product is moldable at temperatures below -1 50C.

m. *Spranggelatin*. This is a blasting gelatin that is prepared by dissolving seven to eight percent collodion cotton in slightly warm nitroglycerin. On cooling, a stiff jelly is formed that is one of the most powerful explosives known.

n. *Startex A*. This is another slurry blasting agent.

o. *Svartkrut*. This is Swedish for black powder. The composition falls within the following limits: potassium nitrate 74 to 78 percent, charcoal 12 to 15 percent, and sulfur 10 to 12 percent. For different grades of black powder, charcoals of different origin and methods of preparation are used. Powders used in shotgun shells contain charcoal from black alder carbonized in furnaces. Ordinary powders use charcoal made from birch, alder, willow, or linden and blasting powders use pinewood charred in kilns or furnaces.

p. *Territ*. This is a cheddite type blasting explosive that consists of 43 percent ammonium perchlorate, 28 percent sodium nitrate, 27.8 percent liquid DNT/TNT, and 1.2 percent collodion cotton. Another formulation is 43 percent ammonium chlorate, 26 percent ammonium nitrate, and 31 percent of a mixture that contains 96 percent TNT and 4 percent nitrocellulose. Territ is comparable in properties to some low freezing point dynamites and is safe to handle. The brisance of the mixture is such that in mining coal or other mining operations, no small dust particulates are formed. Territ is sometimes difficult to detonate so present formulations contain some nitroglycerin.

11-9. Swiss Energetic Materials. In Switzerland the production of black powder and propellants is a monopoly of the government. The Swiss government, however, does not manufacture explosives except for small quantities of primary explosives. Commercial firms produce the explosives used by the army under strict control by military authorities. Switzerland does not generally export military explosives, however, during times of low usage some export has taken place to keep facilities open. Table 11-21 lists some of the explosives used by the Swiss.

Table 11-21. Swiss Explosives

English	Swiss
Lead styphnate	Bleitrinitroresorzinat, bleistyphnat
Nitroglycerin	Nitroglycerin
PETN	Pentaerythrit-tetranitrat, nitropentaerythrit, pentrit
TNT	Trinitrotoluol, trotyl

a. *Aldofit*. This is a permissible explosive that contains 81 percent ammonium nitrate, 17 percent TNT, and 2 percent woodmeal.

b. *Ammonpentrinit*. These are blasting explosives with the compositions shown in table 11-22.

Table 11-22. Ammonpentrinits

Compositions	1	2	3	4	5
PETN (%)	40.9	40.6	37.0	31.0	33.8
Nitroglycerin (%)	40.9	7.6	7.2	7.5	50.7
Nitroglycol (%)	-	2.6	2.0	-	-
Collodion cotton (%)	1.6	-	0.8	0.5	0.5
Ammonium nitrate (%)	16.6	47.5	48.0	59.0	15.0
DNT (liquid) (%)	-	-	5.0	-	-
Vaseline (%)	-	1.7	-	2.0	-

Compositions with collodion cotton are also called gelatinepentrinit. Aluminum can be incorporated to increase the blast effect of the explosives.

c. *Amolit*. This is the trade name of afree flowing bulk packaged ANFO.

d. *Detonierande Zundschnur (Krallzundschnur*). This is Swiss for detonating cord. One such cord contains a core of PETN or RDX in a gel of collodion cotton and a liquid explosive such as nitroglycerin or nitroglycol. This formulation is coated on several textile threads and covered with a fabric coating.

e. *Gelatine Cheddit*. This is a plastic chlorate explosive which contains 79 percent sodium chlorate, 5 percent of a liquid mixture of castor oil that coats the sodium chlorate, 2 percent liquid DNT, and 14 percent TNT that has been preheated to 40°C. Some collodion cotton may also be incorporated into the mixture.

f. Gelatine Penthrinits. These are plastic, nonexudable, explosive blends of PETN and nitroglycerin and other ingredients. If the amount of PETN in the formulation is below 60 percent, 6 to 7 percent collodion cotton is added to improve plasticity. Compositions of some of the gelatine-penthrinit and penthrinit are given in table 11-23.

g. *Hexal*. This is an antiaircraft ammunition filler that contains RDX and aluminum. The aluminum is coated with a water insoluble wax to prevent wateraluminum reactions that release hydrogen.

h. *Hexonite*. These are plastic explosives. One formulation consists of from 20 to 50 percent RDX and 80 to 50 percent nitroglycerin. Another formulation consists of 50 percent RDX, 46 percent nitroglycerin, and 4 percent collodion cotton.

i. *Matter Explosives*. These explosives are named after their inventor 0. Matter. One explosive is a gelatin dynamite that consists of tar distillates mixed with inorganic oxidizers such as nitrates, chlorates or perchlorates. Another formulation uses water soluble chlorinated hydrocarbons such as chloronaphthalene as a fuel with a thickening agent.

j. *Nitrogelatinedynamit*. These are the gelatin dynamites that contain 20 to 25 percent nitroglycerin gelatinized with collodion cotton, ammonium nitrate, and a liquid aromatic nitrocompound serving as a sensitizer. The nitroglycerin may be a 4:1 mixture of nitroglycerin and an antifreeze such as nitroglycol. The liquid aromatic nitrocompound may be drip oil which is a byproduct of TNT manufacture. Some explosives which belong to the class sicherheitsdynamite (safe to handle and transport) include aldorfit, gamsit, and telsit.

Table 11-23. Penthrinits

Composition and properties	Penthrinits						Gelatine penthrinits			
	1	2	3	4	5	6	1	2	3	4
PETN (%)	80	85	70	50	40	80	50	59.0	15.5	50
Nitroglycerin (%)	20	15	30	50	60	15	46	24.7	77.5	46
Nitroglycol (%)	-	-	-	-	-	5	-	-	-	-
Collodion cotton (%)	-	-	-	-	-	-	4	0.6	7.0	4
NH_4ClO_4 (%)	-	-	-	-	-	-	-	15.7	-	-
Al (added) (%)	-	-	-	-	-	-	-	-	-	30

k. *Nizol*. This is an explosive that contains meta dinitrobenzene made more sensitive to initiation by the addition of 30 percent PETN. The mixture is castable because of meta dinitrobenzene's low melting point, 800C.

I. *Pentostit*. This is the trade name for a military explosive in which PETN is desensitized with pentaerythritol tetrastearate.

m. *Pentro*. This is petrtolite, which is also called pentryl.

n. *Plastolit*. This is a safe to handle plastic explosive that contains 57 percent sodium nitrate, 15 percent nitroglycerin, 4 percent nitroglycol, 1.3 percent collodion cotton, 13 percent liquid DNT, 9.6 percent woodmeal, and 0.1 percent sodium bicarbonate.

o. *Totalit*. This is a military explosive used as a bursting charge that contains 95.5 percent ammonium nitrate and 4.5 percent paraffin wax.

p. *Tramex*. This is the trade name for a powdered nitroglycerin sensitized explosive.

CHAPTER 12

TOXICITY OF ENERGETIC MATERIALS

12-1. General. This section contains general information about toxicity of military explosives. All tables indicating quantity distance separations, minimum distances, etc., have been removed from this manual. Applicable information may be found in DoD 6055.9STD, Ammunition and Explosives Safety Standards.

12-2. Toxicity of United States Military Explosives.

a. Many explosives, because of their chemical structures, are somewhat toxic. To be acceptable, a military explosive must be of minimum toxicity. Careful attention must be paid to this feature because the effects of toxicity may vary from mild dermatitis or a headache to serious damage to internal organs.

b. Table 12-1 is a concise presentation of the toxicological properties of selected United States military explosives.

Table 12-1. Toxicity of United States Military Explosives

Explosive	Health hazard	Protective measures
Initiating explosives		
Lead azide	Lead azide is not considered to be particularly toxic but inhalation of the dust should be avoided since this causes a headache and distention of the blood vessels.	Avoid inhalation. Tolerance level below 0.2 milligrams per cubic meter in air.
Mercury fulminate	Poisoning has symptoms of mercury poisoning. At low levels causes dermatitis and irritation of the mucous membranes.	Avoid all routes of exposure. Tolerance level below 0.01 milligrams per cubic meter in air.
Boostering explosives		
PETN	PETN is not unduly toxic since it is nearly insoluble in water and usually is handled while wet. It, therefore, cannot be absorbed through the skin and inhalation of the dust is improbable. Tests have shown that small doses of PETN cause decrease in blood pressure; larger doses cause dyspnea and convulsions.	
Tetryl	Moderately toxic by inhalation or ingestion. Tetryl has a strong coloring action on the human skin and can cause a dermatitis.	Avoid inhalation or ingestion. To minimize these effects, use cold cream containing 10 percent sodium perborate.
	Inhalation of tetryl dust has recognized toxic effects.	Avoid inhalation. Tolerance level below 1.5 milligrams per cubic meter in air.

Table 12-1. Toxicity of United States Military Explosives (Cont)

Explosive	Health hazard	Protective measures
RDX	Munitions workers have experienced acute RDX intoxication, mainly from inhaling the fine particles; ingestion may have been a contributing factor. Troops have occasionally suffered symptoms of RDX intoxication following consumption of Composition C-4, a plastic explosive containing 91 percent RDX. Composition C-4 was chewed by soldiers to produce the "high" of ethyl alcohol or it was used as a fuel for cooking. In the latter case, the victims may have inhaled the fumes or inadvertently introduced RDX into their food. Acute effects were seen within a few hours of exposure, ie, after a latent period. The course of acute RDX poisoning appears to follow a general sequence, though some symptoms may be missing in any individual case: restlessness and hyperirritability; headache; weakness; dizziness; severe nausea and vomiting; aggravated and prolonged epileptiform seizures (generalized convulsions) which are often repeated; unconsciousness between or after convulsions; muscle twitching and soreness; stupor, delirium, disorientation and confusion; then gradual recovery accompanied in the beginning by amnesia. In a few cases, workers have suffered irritation to the skin, mucous membranes, and conjunctivae by fine particles of RDX. The clinical findings in RDX intoxication may include fever; rapid pulse; hematuria due to effects on the. proximal tubules of the kidney; proteinuria; azotemia; occasional mild anemia; neutrophilic leukocytosis; elevated SGOT (serum glutomic oxalacetic transaminase), which may explain the muscle soreness; nitrites in the gastric juices; and electroencephalographic abnormalities. There appears to be no liver involvement and cerebrospinal fluid is normal. Patients evidently recover completely from the effects of RDX poisoning, the length of time depending on the extent of exposure. The period of recovery varies from a few days to about three months. Thus, RDX intoxication involves gastrointestinal, central nervous system, and renal effects. The potential routes of exposure are inhalation of fine particles or fumes, or ingestion. Because RDX is a high-melting solid and not very lipid soluble, skin absorption is very unlikely. Although the symptoms may be severe, deaths have apparently been quite few, and no permanent damage seems to have resulted among survivors.	Avoid inhalation or ingestion.

Table 12-1. Toxicity of United States Military Explosives (Cont)

Explosive	Health hazard	Protective measures
Bursting charge explosives		
Amatol	Highly to moderately toxic by inhalation, ingestion, and absorption. Contact may cause dermatitis.	Avoid inhalation, ingestion, or skin contact.
Ammonium picrate	Highly toxic by inhalation, ingestion, and skin absorption.	Inhalation of the dust should be minimized and frequent baths and changes of clothes are desirable for those working with the material in quantity.
DBX	Generally considered non toxic.	
HBX-6 or H-6	Highly toxic by inhalation or ingestion.	Avoid inhalation and ingestion.
HMX	The low solubility of HMX has caused difficulties that have cast in doubt the validity of all toxicological research done on this compound to date. It would appear that, weight-for-weight, HMX is somewhat less toxic than RDX but exhibits similar effects. Experiments are in progress to confirm or contradict this opinion.	
Pentolite	See TNT and PETN.	
Picratol	See TNT and ammonium picrate.	
RDX compositions	See RDX - boostering explosives.	
Tetrytol	See TNT and tetryl.	
TNT	TNT exposures can occur by inhalation of the dust, through ingestion, and via skin absorption. Among the first signs of TNT intoxication are changes in the blood: the red blood cell count and hemoglobin content decrease; abnormal red cells are seen; and there is a transitory increase in leukocytes and lymphocytes. Rashes and skin eruption may be associated with these effects. Increased capillary fragility leads to nose bleeds and hemorrhages of the skin and mucosa. At sufficiently high and prolonged exposures, more serious blood phenomena appear. These include methemoglobinemia, with consequent cyanosis; hyperplasia of the bone marrow leading to aplastic anemia (because the marrow no longer produces blood cells); and a drastic loss of blood platelets. Petechiae often occur in conjunction with aplastic anemia.	Avoid inhalation and skin contact. Tolerance level below 1.5 milligrams per cubic meter in air.

Table 12-1. Toxicity of United States Military Explosives (Cont)

Explosive	Health hazard	Protective measures
	A second type of symptom, toxic jaundice, indicates toxic hepatitis. This ultimately leads to yellow atrophy of the liver. Death can occur from either anemia or (especially in younger people) toxic hepatitis. Effects of TNT on the kidney are manifest in increased filtration rates. In mild cases of TNT intoxication, urgency, frequent urination, and lumbar pain may be the only symptoms. Individuals exposed to TNT may complain of a constant bitter taste, excessive salivation, nausea, vomiting, and gastritis. The latter is due to reduced secretion of pancreatic eazymes. According to European accounts, chronic work-place exposure to TNT was associated with cataracts of the eyes. There have been various reports of central nervous system intoxication (neurasthenia, polyneuritis). No carcinogenic effects of TNT on human beings have been reported.	
Torpex	See TNT.	
Tritonal	Highly toxic by inhalation and ingestion.	Avoid inhalation and ingestion.
Solid propellants		
Single-base propellants		
Nitrocellulose	Nitrocellulose is a water-insoluble fibrous polymer. Consequently it is not absorbed through the intestinal wall or cell membranes. This accounts for its total lack of oral toxicity to mammals. Subchronic and chronic feeding to rats and dogs at contents as high as 10 percent and to mice at 3 percent of the solid diet resulted in no effects other than those of fiber bulk, ie, as if they had been fed cotton linters. Suspended nitrocelluldse in concentrations as high as 1,000 milligrams per liter showed no effect on four species of fish and four invertebrates in various acute toxicity tests.	Adequate ventilation is recommended.

Table 12-1. Toxicity of United States Military Explosives (Cont)

Explosive	Health hazard	Protective measures
Double-base propellants		
Nitrocellulose	See nitrocellulose above.	
Nitroglycerin	Nitroglycerin has been used as a vasodilator drug in medicine, especially for the treatment of angina; thus, there is a fairly extensive literature on its biochemical and clinical aspects. The most common medicinal dose is 0.65 milligrams (roughly 0.01 milligrams per kilogram), but many patients safely receive 20 times this (about 0.2 milligrams per kilogram) daily. Survival has been noted after quantities up to 400 milligrams (about six milligrams per kilogram) were administered orally or sublingually. Two of the more noticeable symptoms are headache and falling blood pressure. Chronic human exposure to nitroglycerin is characterized by methemoglobinemia and the development of tolerance to the drug. Withdrawal from frequent exposure to nitroglycerin causes severe headaches, "Monday head," among munitions workers. Since nitroglycerin is not very volatile, skin absorption is the most likely route of exposure. A TLV of 0.2parts per million, or 2 milligrams per cubic meter, in air was adopted by the American Conference of Government Industrial Hygienists in 1972, to encompass cutaneous exposure - including mucous membranes and the eye - as well as inhalation. But a reduction in this value may be desirable in view of withdrawal headaches suffered by volunteers after exposure to such a level.	Avoid inhalation or skin contact.
Military pyrotechnics		
HC smoke mixtures	Moderately toxic by inhalation and ingestion. Skin contact can cause dermatitis.	Avoid inhalation, ingestion, and skin contact.
Black powder	Moderately toxic by inhalation and ingestion.	Avoid inhalation and ingestion.

(12-7 thru 12-30 deleted)

CHAPTER 13
DETECTION AND IDENTIFICATION OF ENERGETIC MATERIALS

13-1. Introduction. This chapter discusses the methods used to detect and identify energetic materials. Almost all of the analytical chemistry techniques are used. Normally, identification involves a series of tests, each providing a clue to the identity of the compound. In addition to the techniques discussed in this chapter, identifying information can be obtained from physical properties such as melting point, crystalline structure, density, physical state, color, and indicies of refraction.

13-2. Wet Chemical Methods. When a test sample is treated with an appropriate reagent, a coloration is produced which is characteristic of the compound being tested. These reactions are known as color reactions and may help identify the sample. The compound which produces the color change is called the color reagent. Color reactions are used to some degree for preliminary identification and confirmation but have largely been replaced by the more modern instrumental techniques. Table 13-1 lists some of the common color reactions used to identify explosives.

Table 13-1. Color Tests

Water Solution or Extract of Energetic Material				Solid of Energetic Material		
	Color of solution	Color of universal pH test	Color of precipitate with Nessler's reagent	Color effect of test with solution of-		
				Ethylenediamine	Diphenylamine	Thymol
TNT	(Insoluble)	-	-	Maroon	Colorless	-
Tetryl	(Insoluble)	-	-	Red	Blue	Green
Picric acid	Yellow	Red	(No ppt)	Orange	-	-
Explosive "D"	Yellow	-	Brown	Orange	-	-
Haleite	None	-	(No ppt)	None	Blue[1]	Orange
Nitroguanidine	None	-	White	-	Blue	Green
Ammonium nitrate	None	-	Brown	None	Dirty green	Green[1]
PETN	(Insoluble)	-	-	None	Dirty green	Green
Nitroglycerin	None	-	(No ppt)	-	Deep blue	Green
DEGN	None	-	(No ppt)	-	Deep blue	Brown[2]
Nitrocellulose	None	-	-	-	Blue	Green
Tritonal	(Insoluble)	-	-	Maroon	Colorless	-
Tetrytol	(Insoluble)	-	(No ppt)	Maroon	Intense blue	Green
Picratol	Yellow	-	Brown	Maroon	-	-
Ednatol	None	Orange	(No ppt)	Maroon	Intense blue	Orange
Amatol	None	-	Brown	Maroon	Dirty green	Green
Ammonal	None	-	Brown	Maroon	Dirty green	Green
Pentolite	None	-	(No ppt)	Maroon	Dirty green	Green
Black powder[3]	None	No change-	-	-	Blue	Green

[1]Color appears immediately.
[2]Sometimes explodes mildly (puffs) upon addition of sulfuric acid.
[3]Tests of dried water extract.

The tests are performed in the following manner.

a. *Test 1*. Place 0.05 gram of the explosive in a 5 milliliter beaker, add 2 to 3 milliliters of distilled water, and stir for 5 minutes.

(1) Observe color of liquid.

(2) Wet one end of a strip of universal pH indicator paper and note any change in color.

(3) Add a drop of Nessler's reagent and note the color of any precipitate formed. Prepare the reagent by dissolving five grams of potassium iodide in a minimum quantity of cold distilled water and adding a saturated aqueous solution of mercuric iodide until a faint precipitate is formed. Add 40 milliliters of 50-percent potassium hydroxide solution. After the solution has clarified by settling, dilute to 100 milliliters with distilled water, allow to settle, and decant.

b. *Test2.* Place 0.05 gram of the unknown material in an indenture of a white porcelain spot-test plate. Add two or three drops of a 65 to 68 percent aqueous solution of ethylenediamine and stir. Note the color of the solution (not the solid).

c. *Test 3.* Place 0.05 gram of the unknown material in an indenture of a white porcelain spot-test plate and add three or four drops of a diphenylamine solution. Stir the mixture and, after one minute, note the color of the solution. Prepare the diphenylamine solution by dissolving one gram of diphenylamine in 100 milliliters of concentrated CP sulfuric acid.

d. *Test 4.* Place 0.05 gram of the unknown material in an indenture of a white porcelain spot-test plate. Add an equal amount of crystalline thymol and three drops of concentrated sulfuric acid. Stir the mixture and note its color after five minutes or more.

e. *Additional Tests*. If the unknown material is not identified completely by the tests in subparagraphs 13-2 a. through d. and data listed in table 13-1, tests should be performed to determine whether the material is one of those indicated in (1) through (14) below.

(1) RDX. Place several milligrams of the white, unknown material in a test tube and add about 200 milligrams of thymol and six drops (0.3 ml) of concentrated sulfuric acid. Warm the tube for five minutes at 100°C, and add 5 to 10 milliliters of ethanol. RDX produces a rich blue color. Under these conditions sugars and aldehydes give a brown color, and HMX gives a pale blue-green color. RDX can be further distinguished from HMX by repeating the test at 150°C. Under these conditions RDX still gives a blue color, but HMX produces an olive color.

(2) Composition A-3. Place 0.1 gram of the material in a 10 milliliter beaker and add two or three drops of acetone. Warm the mixture and allow to stand for five minutes. Evaporate the acetone by gently warming on a steambath, cool, and add 2 milliliters of carbon tetrachloride. Cover the beaker and warm the contents, occasionally swirling the mixture. Cool the mixture and allow the undissolved material to settle. Decant the supernatant liquid into a 5 milliliter beaker, evaporate to dryness, and note if a waxy (not tarry) residue is obtained. Dry the undissolved material in the 10 milliliter beaker and test for RDX as described in (1) above.

(3) Composition B. Place 0.2 gram of the pale yellow to medium brown material in a 10 milliliter beaker and add 2 to 3 milliliters of chloroform. Cover the beaker. Warm and digest the mixture for 10 minutes with occasional swirling. Decant the supernatant liquid through a filter paper and evaporate the filtrate to dryness. Repeat digestion of the insoluble residue in the beaker with three more portions of chloroform discarding the decanted liquid in each case. Dry the insoluble residue by evaporating any adherent chloroform. If the original material was composition B, the residue from the chloroform solution consists of TNT and wax. Test the TNT and wax mixture with ethylenediamine and diphenylamine as described above. The insoluble residue obtained by extraction with chloroform consists of RDX. Test as described in (1) above.

(4) Composition C-3. Place 0.2 gram of the putty-like explosive in a 10 milliliter beaker and add 5 milliliters of benzene. Mix and digest for 10 minutes crushing any lumps present. Decant the supernatant liquid through a filter paper and evaporate the benzene with gentle heating. Note whether a dark, tarry residue remains. Wash the insoluble residue left by benzene extraction with two or three, 3 milliliter portions of a 2: 1 ether-ethanol mixture and dry the washed residue. Test this as described under RDX in (1) above. To the decanted ether-ethanol washings, add 15 milliliters of distilled water and heat the mixture until all ether and alcohol are removed. If a white precipitate (nitrocellulose) is noted, catch the precipitate on a filter, wash with ethanol, dry by evaporation of the ethanol, and test for nitrocellulose as indicated in table 13-1.

(5) Torpex. Place 0.2 gram of the explosive in a five milliliter beaker and extract with three, 3 milliliter portions of acetone. Dry the insoluble residue and examine under a microscope. Note if the residue has the characteristic appearance of metallic aluminum. Place 0.2 gram of the explosive in a 5 milliliter beaker and digest with two, 3 milliliter portions of benzene, decanting the benzene into a small evaporating dish. Evaporate the benzene solution to dryness and test for TNT as indicated in table 13-1. Dry the insoluble residue from the benzene extraction and test for RDX as described in (1) above.

(6) Tritonal. Place 0.2 gram of the explosive in a 10 milliliter beaker and add 5 milliliters of acetone. Stir, allow any undissolved material to settle, and decant the liquid. Wash the insoluble matter with two, 5 milliliter portions of acetone, dry, and examine under a microscope. Note if the insoluble matter has the characteristic appearance of metallic aluminum. Subject the separated explosive to the tests prescribed for TNT in table 13-1.

(7) Amatol. Place 0.2 gram of the yellow material in a 5 milliliter beaker, add 3 milliliters of distilled water, and stir for five minutes. Decant the liquid through a filter and evaporate to dryness. Test the dried solid as prescribed for ammonium nitrate in table 13-1. Dry the water-insoluble residue and test as prescribed for TNT above.

(8) Ammonal. Place 0.2 gram of the explosive in a 10 milliliter beaker and digest with 3 milliliters of distilled water. Decant the liquid through a filter and evaporate to dryness. Test the dried solid as prescribed for ammonium nitrate. Digest the insoluble residue in the beaker with three, 3 milliliter portions of acetone decanting these through a filter. Dry the insoluble residue and examine under a microscope. Note if the residue has the characteristic appearance of metallic aluminum. Evaporate the filtrate to dryness by warming gently. Test the dried solid as prescribed for TNT above.

(9) Lead azide.

(a) Test the explosive for solubility in water. Lead azide is insoluble in water.

(b) Transfer 5 milligrams of the sample explosive to a 1 O0-milliliter beaker and add 10 drops of a 1 0-percent ceric ammonium nitrate solution. A reaction accompanied by evolution of nitrogen oxides (red fumes) is indicative of the presence of azide.

(c) Treat the solution of the sample obtained in (b) above with a few drops of a 10 percent aqueous solution of potassium dichromate. A yellow to reddishyellow precipitate is indicative of the presence of lead.

(d) Transfer 2 milligrams of the sample to a5 milliliter beaker. Add 5 milliliters of a 10 percent aqueous solution of ferric chloride solution. A red color is formed which disappears slowly when 2 to 3 milliliters of dilute mercuric chloride solution are added. This confirms that the explosive is lead azide.

(10) Mercury fulminate.

(a) Test the explosive for solubility in water. Mercury fulminate is insoluble in water.

(b) Transfer 10 milligrams of the sample explosive to a fritted glass crucible of medium porosity. Extract the sample with a 20 percent aqueous solution of sodium thiosulfate, catching the washings in a 50-milliliter beaker containing 10 drops of a one percent phenolphthalein indicator solution. When the mercury fulminate is treated with sodium thiosulfate, it dissolves with formation of alkali (NaOH) which changes the color of the indicator solution from colorless to red.

(c) Transfer 10 milligrams of the sample to a 1 0-milliliter beaker and add three drops of concentrated hydrochloric acid solution and 2 milliliters of water. Transfer the solution to another beaker containing one drop of a five percent aqueous solution of potassium iodide. The formation of a bright red precipitate indicates the presence of the mercuric ion.

(11) Diazodinitrophenol (DDNP). Dissolve 0.05 gram of the greenish-yellow to brown explosive in acetone. Upon adding a larger volume of ice water, the explosive should appear as bright yellow crystals. Prepare a saturated solution of the explosive in 200 milliliters of water. Add to this 5 milliliters of a 20 percent solution of sodium hydroxide and mix. The evolution of a colorless gas and the appearance of a reddish-brown color in the solution indicate the explosive to be diazodinitrophenol.

(12) Lead styphnate. Wet 0.1 gram of the heavy, light orange to reddish-brown material with 10 milliliters of water and then add slowly 10 milliliters of a 20 percent solution of ammonium acetate. Agitate the mixture until solution is complete. Add 10 milliliters of a 10 percent aqueous solution of potassium dichromate. The appearance of a bright yellow precipitate indicates the presence of lead. To 0.1 gram of the explosive in a beaker add 10 milliliters of a 10 percent solution of hydrochloric acid. Heat the mixture in a steambath and evaporate to dryness. Cool the beaker and contents and add 10 milliliters of ether. Mix the contents and allow to settle. Decant or filter off the yellow ether solution and evaporate this to dryness at ordinary temperature. Dissolve the residue in 25 milliliters of water and add 0.1 gram of solid potassium cyanide. The absence of color indicates the explosive to be lead styphnate.

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(13) Tetracene. Wet 0.25 gram of the fluffy, pale yellow explosive with 5 milliliters of a 10 percent solution of sodium hydroxide and warm the mixture in a steambath until solution is complete. Note if there is an odor of ammonia. Cool the solution and add 1 milliliter of a five percent solution of copper acetate. The appearance of a bright blue precipitate indicates the explosive is tetracene.

(14) Black powder. Place 0.2 gram of the black material in a 5 milliliter beaker, add 2 to 3 milliliters of distilled water, and stir for five minutes. Decant the liquid through a filter and catch the filtrate in a beaker. Evaporate this to dryness and subject the dried white solid to the tests shown in table 13-1. Dry the water-insoluble residue in the beaker, cool, and digest with two 5 milliliter portions of carbon disulfide, decanting these into an evaporating dish. Evaporate the carbon disulfide solution to dryness at room temperature. By means of a microscope, examine the yellow residue so obtained and the insoluble black residue from the carbon disulfide extraction. Note if they have the characteristic appearances of sulfur crystals and charcoal, respectively.

13-3. Chromatography.

a. *Column Liquid Chromatography*. This is the oldest form of chromatography and is sometimes called column chromatography. The equipment consists of a vertical glass or quartz column which is constricted at the lower end. The column is filled with a fine, granulated material which is most commonly silica gel but may be metal oxides (alumina), sugars, etc. This is called the stationary phase. A chemical mixture in a suitable solvent is placed in the top of the column and allowed to diffuse downward. The solvent is called the mobile phase. Vacuum is sometimes applied to the bottom of the column. The chemical components of the mixture will diffuse at different rates due to their difference in affinity for the column material. After sufficient time the components will be separated into bands along the length of the column. If the components are colored, the bands can be easily detected. Colorless or white component bands can be detected by adding a fluorescent material to the column material contained in a quartz column and irradiating with ultraviolet light. The column is then extruded from the tube and cut into bands. The separated compounds in the bands are eluted by suitable solvents and subjected to quantitative and qualitative analyses procedures. The solvent has a significant effect on the interaction between the material under test and the column material. Therefore, the proper combination of column material and solvent must be used for each material under test. Column liquid chromatography has been implemented by other modern chromatographic techniques because the procedures are time consuming and tedious.

b. *Paper Chromatography*. In paper chromatography both the stationary and mobile phase are liquids. The stationary phase liquid, which is usually water, is supported on a filter paper. A spot of the mixture to be tested is placed on the filter paper. The spot is then dried. The filter paper is then placed in a trough which contains the mobile phase. The liquid mobile phase is immiscible with the liquid of the stationary phase. The mobile phase is usually a mixture of organic solvents. The eluent is allowed to migrate either upward or downward on the paper. As the eluent migrates, the compounds in the mixture separate, each traveling with the eluent but at a different rate. After the eluent front has advanced between 15 and 30 centimeters the paper is removed from the trough and dried. A color reagent is sprayed on the paper to locate all the separated compounds. The ratio of the distance traveled by the separated compound to the distance traveled by the eluent front is then computed. In some cases the filter paper is impregnated with hydrophobic substances such as oils or paraffins and the mobile phase is aqueous. This is called reverse phase paper chromatography. Most work with energetic material has been done using the reverse phase technique. Paper chromatography is not generally used for identification of energetic material as is thin layer chromatography.

c. *Thin Layer Chromatography*. A thin layer chromatographic plate consists of a thin layer of powdered material mixed with a binder that is applied to a smooth surface such as a glass, aluminum, or plastic sheet. The powdered material, which constitutes the stationary phase, usually consists of silica gel or aluminum oxide of uniform particle size. A solution of the mixture to be tested is spotted near the bottom of the plate. The plate is then placed vertically in a trough of solvents, called the developing solvents, contained in a closed developing tank. The level of the developing solvent in the trough is below the spot of test material. The developing solvents constitute the mobile phase. The mobile phase is drawn up into the stationary phase by capillary action. As the level of the mobile phase rises, the compounds of the test mixture are separated, each traveling with the mobile phase but at different rates. The liquid phase is allowed to rise to the desired level, usually near the top, and the plate is removed from the trough and dried. Colorless spots are detected by either spraying with a color reagent or incorporating a fluorescent material in the chromatographic plate such

that exposure to ultraviolet light will cause luminescence except where spots of ultraviolet absorbing compounds are present. The rate of flow is defined as the ratio of the distance traveled by the compound to the distance traveled by the developing solvent. The rate of flow is affected by many factors such as the plate material, the developing solvent used, plate thickness, dryness of the plate, temperature, and others. Therefore compound identification is made by running the test solution on the same plate as known compounds, not by comparing the rate of flow to published data. When more than one elution is required, thin layer chromatography can be run in two dimensions. The plate is spotted near one of the corners at the bottom. Then the plate is developed normally in a developing solvent that separates the mixture into groups rather than single compounds. The plate is then dried, rotated 90° so that the separated groups are along the bottom, and placed in a second solvent trough. The second solvent separates the groups into single compounds. Thin layer chromatography is used extensively as a qualitative analysis technique. The developing solvents and plate material used vary according to the test material so no single combination of solvent and material can be used for separating all the energetic materials.

d. *Gas Chromatography.* In gas chromatography the vapor of the material to be tested is injected into a stream of inert gas such as nitrogen, and passed through a column. The carrier gas is the mobile phase, the material in the column is the stationary phase. The stationary phase can be either a solid or a liquid supported on a solid. If the stationary phase is solid the method is called gas-solid chromatography (GSC). If the stationary phase is a liquid supported on a solid then the method is called gas-liquid chromatography (GLC). Two types of columns are used in GLC; packed columns, which contain an inert nonvolatile liquid, and capillary columns, which are long, open tubes of small diameter that have a thin, liquid film on their inner surface. Capillary columns offer a greater resolution of mixture. As the carrier gas flows through the column the components of the test mixture separate, each traveling through the column material at a different rate. A detector at the end of the column detects when the gas being tested emerges. Three types of detectors are commonly used; thermal conductivity, flame ionization, and electron capture. A thermal conductivity detector detects changes in the thermal conductivity of the carrier gas. This type detector is simple and nondestructive but the sensitivity is low and the test results are highly dependent on gas temperature and rate of flow. A flame ionization detector measures the electrical conductivity of the product gases when the carrier and test sample are decomposed in an air/hydrogen flame. This type detector is destructive but more sensitive and does not have a great dependence on the gas temperature. The current carried across the product gas is proportional to the number of carbon atoms but inversely proportional to the number of oxygen and nitrogen atoms. This is the most commonly used detector. An electron capture detector uses a radioactive beta emitter to ionize the carrier gas. An electron capturing compound will remove some of the ions. The resulting decrease in the current carrying capability of the gas indicates the presence of one of these compounds. This method of detection is very sensitive to electronegative compounds, but is insensitive to compounds such as hydrocarbons which do not capture electrons. The detector output is recorded as a function of time, as shown in figure 13-1. Each peak corresponds to a compound in the mixture. There is a general correlation between the area under the peak and the content of the compound in the mixture. However, the area ratio for two compounds does not necessarily represent their weight ratio in the sample. This could be due to several reasons: difference in the detector response for different compounds, adsorption or decomposition of a compound before detection, or a faulty sampling technique. Therefore, to use the recorder output quantitatively a specific amount of a known compound is added to the sample. The sample must react similarly in the gas chromatographic unit to the unknown. Relative weight percentages can then be computed by comparing the area under the curve for the unknown and known sample. Gas chromatography is used for energetic materials, however, in some cases, application of this method is limited by the high temperature at which the test must be run. Nitroaromatics are generally stable at their boiling point, but nitramines and aliphatic nitrated esters are not. For the unstable compounds several techniques are recommended to reduce decomposition; glass rather than metal columns, short column length, lower temperatures, low polarity liquid in the GLC stationary phase, and low loading percentage of the liquid. These precautions also minimize reaction between the compounds in the column. This is a consideration when analyzing the stabilizer content of propellants as the higher temperature tends to drive off nitrogen oxides from the aliphatic nitrated ester and nitrate the stabilizer. Gas chromatography can be run isothermally or with a programed temperature change.

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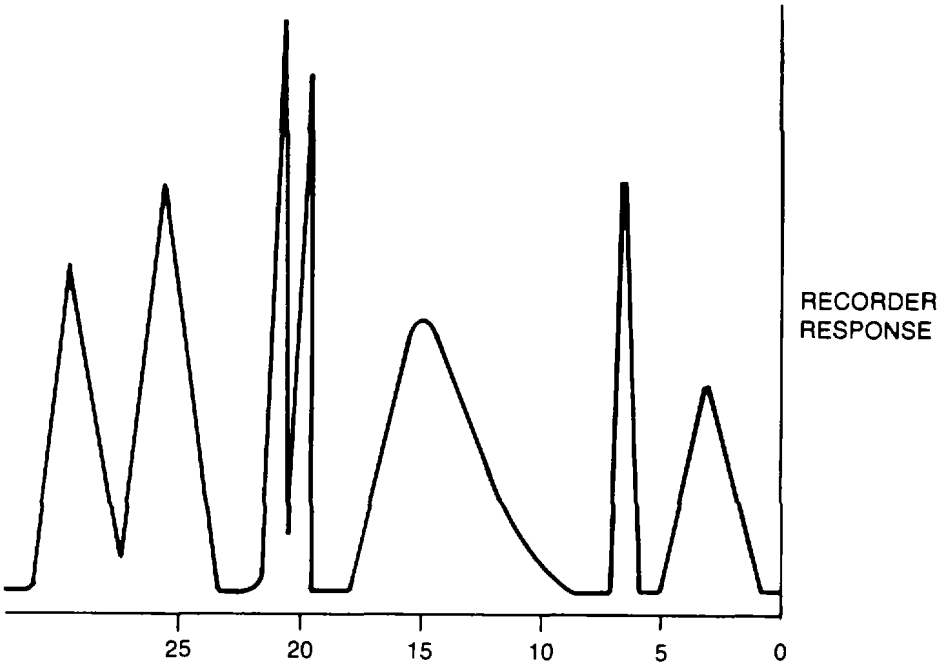


Figure 13-1. Gas chromatograph output.

e. *High Performance Liquid Chromatography (HPLC). HPLC* is also known as high speed or high pressure liquid chromatography. Separation is done in a glass or stainless steel column that is packed with a fine powdered material, usually silica. Column dimensions are usually 15 to 30 centimeters in length and three to four millimeters in diameter. The packing material, or stationary phase, consists of particles in the 5 to 10 micrometer diameter range. A solvent, the mobile phase, is pumped through the column under pressure in the range of 1,379 to 6,895 kilopascals (200 to 1,000 pounds per square inch). The test mixture to be separated is injected. Separation in the column is accomplished in the same manner as in the other forms of chromatography: the various constituents diffuse down the column at different rates. The composition of the mobile phase can be held constant (isocratic elution) or varied (gradient elution) during the procedure to improve separation. When the column material is silica, surface adsorption is the mechanism of separation. When the silica is coated with a liquid, partition between the two liquid phases is the separation mechanism. The liquids of the stationary and mobile phase must be immiscible. Normal HPLC is performed with a polar stationary phase and a somewhat nonpolar mobile phase. Reverse phase HPLC is performed with a non-polar stationary phase and polar mobile phase. Another column material is the chemically bonded stationary phase. Silica contains free hydroxyl groups. The hydrogen can be replaced by organic compounds, although direct replacement with a carbon bond is less stable than bonding the oxygen to another silicon which is bound to the organic compound. As the mobile phase emerges from the column an ultraviolet spectrophotometer is used to detect the test material in the eluent. The detector output is plotted as a function of time. The graph obtained is very similar to the one shown in figure 13-1. The area under the peaks in the curve is proportional to the concentration of each component in the test material. A tentative identification of the compounds in the mixture can be made by comparing the graph of the output of the unknown to the graph for known compounds run under the same conditions. This identification, however, is not as specific as other methods and cannot be used in forensic work, for example, where an exact identification is required. The separated compounds can be collected and analyzed individually using one or a combination of other methods for positive identification such as mass spectrometry, infrared spectrometry, and nuclear magnetic resonance.

f. *Ion Chromatography*. Ion chromatography is instrumentally very similar to HPLC, the difference between the methods being the column material. Ion chromatography uses an ion exchange resin stationary phase which can be applied to glass microbeads for packing. While HPLC is based on absorption and partiti6n phenomena, ion chromatography is based on the exchange of ions between the resin and the mobile phase. It is a very good technique for separating cations and anions from each other.

13-4. Polarography. Polarography measures current in microamperes, generated through the reduction/oxidation of chemical species in an electrolytic solution at an applied potential specific to the specie. A reference electrode and polarizable electrode are used. The polarizable electrode normally used is the Dropping Mercury Electrode (DME) which consists of a glass capillary filled with mercury. The mercury is allowed to drip from the capillary at a controlled rate. As a droplet forms at the end of the tube the surface area of mercury exposed to the solution increases. This causes an increase in the current conducted through the solution at any given voltage. There is a sharp decrease in the current when the drop falls. The current then increases during the formation of the next drop. Several forms of polarography are used: DC, single sweep, AC, and differential pulse. These four forms differ only in the manner in which voltage is applied between the electrodes. In DC polarography, a DC potential, which is increasing linearly at the rate of 1 to 10 millivolts per second, is applied between the electrodes. At low voltages a small current, called the residual current, flows. This current is due to charging the capacitance between the DME and the solution and miscellaneous impurities in solution. At a critical voltage depending on the chemical specie the current begins to increase with increasing voltage. The current continues to increase until a maximum current is attained, at which point further increases in voltage do not increase the current. The plot of the applied voltage versus the current is called a polarogram. The difference between the residual current and maximum current is called the diffusion current. The diffusion current is proportional to the concentration of the chemical specie. In single sweep polarography, a DC potential increasing at the rate of 100 to 500 millivolts is applied between the electrodes. The voltage is applied at a specific time during the formation of the mercury drop. The applied voltage is plotted against the current to obtain a polarogram. Single sweep polarography is more accurate than DC polarography because the shorter time frame in which the measurement is made allows less change in the surface area of the mercury drop. In AC polarography, a small AC signal is placed on the DC waveform used in DC polarography. The effects of the DC potential are electronically removed and a polarogram with peaks in the waveform is obtained. In differential pulse polarography, a pulse is applied just as the mercury drop attains maximum size. The pulse has an amplitude of 5 to 100 millivolts and a width of 50 to 60 milliseconds. The current is measured twice, just before the pulse and during the last 10 to 20 milliseconds of the pulse. The type and concentration of species present is made by comparing polarograms. Polarography is a very sensitive method of detection. Applications include pollution control and analysis of sensitive material such as primary explosives, in which sample sizes are held to a minimum because of safety considerations.

13-5. Spectroscopy and Spectrometry.

a. *Ultraviolet and Visible Spectroscopy*. In ultraviolet and visible spectroscopic techniques, a solution of the sample to be analyzed is irradiated with discreet frequencies from the entire range of either the ultraviolet or visible spectrum. To obtain a spectrum of the component, the absorbance, which is defined as the log of quotient of the intensity of the incident and transmitted radiation, is measured and plotted as a function of the frequency of the incident radiation. Usually a blank sample, which consists of only the solvent, is run at the same time so the absorbance of the solvent can be subtracted from the total absorbance of the solution. Ultraviolet and visible spectra are not generally used to identify energetic materials because they are not distinctive. However, the methods may be used for quantitative analysis. The concentration of the compound in solution is determined by measuring the absorbance of the material under test and comparing the value obtained to the value obtained for a solution of the same compound with a known concentration. The same solvent, temperature, and optical path length through the solution must be used. With a limited number of exceptions, the concentration is a linear function of the absorbance.

b. *Infrared Spectroscopy*. Infrared spectroscopy is one of the most widely used methods of identification. The technique can be used with gases, solids, or liquids. Gases or liquids are contained in cells containing salt windows, such as sodium chloride or potassium bromide, that are transparent to infrared radiation over a certain wavelength range. Solids may be in solution in which case a blank cell that contains only the solvent is tested in tandum with the material under test to compensate for the effects of the solvent. Solids may also be prepared for testing by grinding with mineral oil and placing between two sodium chloride plates or grinding with potassium bromide and pressing into a pellet. The mineral oil interferes with the spectra over a small wavelength range, but the potassium bromide does not. In the identification of an explosive ingredient, the spectrum of the unknown is examined and classified in terms of groups present in the molecule (OH; NH; C =0; N-NO_2; aromatic NO_2; C-O-C; C-O-NO_2; etc.) and then compared with the standard spectra that contain the same groups. Table 13-2, which gives spectral correlations of aromatic nitro compounds, nitramines, and nitrates, is useful for this purpose. Using infrared spectroscopy for identification depends on having a library of spectra for comparison to the spectra of unknowns. The spectra can be digitized and a computer used to search rapidly among known spectrum. Usually the programs do not identify the compound completely, but narrow the possibilities to about 10 compounds. Infrared spectroscopy is most effective when the sample is a pure compound, so separation techniques such as solvent extraction or chromatography may be used on a sample before irradiation.

Table 13-2. Spectral Correlations of Aromatic Nitro Compounds, Nitramines, and Nitrates

Structure	Band assignments, µm	Comments
sym-trinitro	9.25	Found in all sym-trinitro compounds examined which have the following additional groups: OC_2H_5, CH_3, OH, C_2H_5, COOH, OCH_3, NH_2. The band appears to shift to about 9.35 im in the presence of acidic groups such as COOH or OH.
m-dinitro	10.85-10.95	Found in all *m*-dinitro compounds examined which have contained the following additional groups: CH_3, C_2H_5, OH, N =NH_2, COOH, CHO, OCH_3, CH_3NH, C_2H_5NH, NO_2 (trinitro). In the trinitro compounds the position of the band has been found from 10.75 to 11.0 µm.
	11.90-12.05	Found in m-dinitro compounds examined where other additional groups, if any, were ortho to the nitro. Not found in*sym*-trinitro compounds but present in 2,3,4- and 2,4,5-trinitrotoluene. Absent in 3,5-dinitrobenzoic acid and 4,6-dinitro-*o*-cresol. It appears that a group meta to the nitro inhibits the band.
o-mononitro	12.7-12.8	Found in all mononitro compounds containing any one of the following groups ortho to the nitro: CH_3, C2H_5, CHO, NH_2, COOH. Not usually found in dinitro or trinitro compounds.
p-mononitro	9.0	Found in all mononitro compounds containing any one of the following groups ortho to the nitro: CH_3, C_2H_5, CHO, NH_2, COOH. Not usually found in dinitro or trinitro compounds.
nitramines	7.8	Found in all nitramines examined. Presumed to be caused by the N-N vibration.
nitrates	6.0	Found in all organic nitrates examined. From the analysis made of methyl nitrate it is presumed that this band is caused by the symmetrical stretching vibration of the $N0_2$.
	7.8	Found in all organic nitrates examined. From the analysis made of methyl nitrate it is presumed that this band is caused by the symmetrical deformation vibration of the NO_2.
	12.0	Found in all organic and inorganic nitrates.

c. *Magnetic Resonance*. Two forms of magnetic resonance are used; nuclear magnetic resonance and electron spin resonance.

(1) Nuclear Magnetic Resonance (NMR). When a charged particle spins, a magnetic field or dipole is produced in a manner analogous to the magnetic field produced by current flowing in a loop of wire. An external magnetic field aligns the dipoles, either with the field or 180 degrees out of phase with the field. The out of phase position, in which the north and south poles are reversed, is referred to as against the field. Alignment with the field is more stable than alignment against the field so the application of suitable frequency electromagnetic radiation will cause the dipoles which are against the field to flip into alignment with the field. The frequency at which this occurs is called the resonant frequency. Any nucleus which has a net spin can flip, but the hydrogen nucleus is the most commonly used in NMR. The hydrogen nucleus consists of a single proton, so this method is referred to as proton magnetic resonance. The frequency at which resonance occurs depends on the nucleus and the surrounding medium. The magnetic field that is used to align the protons also changes the configurations of the electrons around the nucleus in such a way that they produce a magnetic field in the opposite direction of the externally applied field. This field shields the nucleus and must be overcome before any of the protons can be flipped. The strength of the field depends on the structure of the electrons around the nucleus. If the atom is bound into a compound and valence electrons are missing, added, or being shared, the effectiveness of the shielding is changed. This alters the resonant frequency for a given magnetic field strength or alters the magnetic field strength required to flip the protons at a given frequency. Either method of scanning, varying the magnetic field strength at fixed frequency or varying the frequency at fixed magnetic field strength, can produce an NMR spectrum. In an NMR spectrum, the resonance of tetramethlylsilane (TMS) is taken as the standard and defined as zero. All twelve of the protons (hydrogen atom nuculei) in the methyl groups are in the same chemical state, so the spectra of TMS consists of one very sharp peak. The resonance peaks in the spectra of other compounds are defined in units of chemical shift, ppm's. The chemical shift of a resonant peak is the frequency of resonance of TMS divided by the spectrometer frequency in megahertz at which the analysis is being performed. Dipoles in close proximity can cause peaks to split into doublets, triplets, etc. The difference between the lines of the multiplet in cycles per second is defined as the coupling constant, J. The value of J yields useful information concerning the positions of the protons in the molecule. The area under the spectra peak is proportional to the number of hydrogen nuclei in a given state. Chemical shift, J, and the area under the peaks provide useful analytical information. Multiple peaks in the spectrum on a single compound are caused by hydrogen nuclei which are in different states. The spectrum of PETN shows one sharp peak because all the protons are in the same chemical state. TNT, however, shows two peaks, one due to the protons in the methyl group and one due to the protons in the ring. The solvent has a considerable effect on the NMR spectrum of a sample, so standard procedures must be used. An exchange takes place between the deuteriums used in the solvent and the active hydrogens in the material under test. This can cause changes in the spectrum: line shifts, intensity shifts, and the creation of new multiplet lines. Stabilized spectra are obtained after the solution has been given enough time to come to equilibrium. This is called the development time. Careful attention must be paid to ensure that the proper development time specified in the specific procedure is used. NMR spectra of unknown compounds can be compared to those of known compounds for identification purposes, or identification can be made on the basis of the analytical information obtained.

(2) Electron Spin Resonance (ESR). This test is sometimes referred to as electron paramagnetic resonance (EPR). ESR can only be performed on samples which contain unpaired electrons. An electron has an intrinsic spin which creates a magnetic dipole along the axis of rotation. In an external magnetic field, the dipoles will align either with or against the field. By applying high frequency energy at right angles to the aligning magnetic field, the magnetic moment, and thus the direction of the electron spin, can be reversed or flipped. Alignment with the field is the preferred direction. Flipping occurs when the frequency of the incident energy is equal to the frequency of precession of the electrons. Flipping does not occur in paired electrons because the opposite spin quantum state is already occupied. Scanning is done by either varying the magnetic field strength at fixed frequency or varying the frequency at fixed magnetic field strength. The former method is preferred. ESR, while of limited applicability to the energetic material field, can be used to identify paramagnetic compounds, transition metal ions, and free radicals of organic compounds. Free radical detection has been used in pyrolysis studies.

d. *Mass Spectrometry (MS).* In mass spectrometry, molecules of the sample to be analyzed are ionized. These ions are then accelerated by an electromagnetic field. The acceleration acquired by each ion in a field of given strength will depend on the fragment's mass and charge. Most of the ions will have a charge of plus one electron unit so separation is on the basis of mass; the more massive of the ions are accelerated less than the fragments having less mass. Two types of electromagnetic fields are generally used for separation: the magnetic selector and the quadrupole. In the magnetic selector, a stream of ions is accelerated to a potential at several kilovolts and introduced into a magnetic field. The direction of the stream is at a right angle to the direction of the field. The magnetic field deflects the path of the ions into a semicircle. The radius of the semicircular path for any fragment for a given magnetic field strength is proportional to the initial or tangential velocity and inversely proportional to the magnetic field strength. A detector is placed at a point in a chosen semicircular trajectory that the ion fragments can travel. For a given initial accelerating potential and magnetic field strength, fragments of a particular mass to charge ratio will strike the detector. The spectra, plotted as a function of the mass to charge ratio, is obtained by scanning the magnetic field strength or the initial accelerating voltage. The former technique is the preferred method in low resolution mass spectrometry. High resolution mass spectrometers use both methods simultaneously to improve separation. In the quadrupole the field produced by a combination of DC and radio frequency power applied to four parallel rods is used to focus the ion fragments rather than a magnetic field. A quadrupole unit is less sensitive than a magnetic selection unit. The ions can be produced by several methods. In electron impact mass spectrometry, the sample is bombarded by electrons boiled off a hot filament. When the sample is ionized in this way organic molecules break up into fragments of various masses. The spectra obtained can be compared with a spectral library to identify unknown compounds, or analytical information from the spectra can be used to identify groups within a molecule. Electron impact of organic compounds produces many products from bond cleavage fragments to complex fragments which have undergone significant rearrangement. In chemical ionization mass spectrometry, the sample reacts with an ionizing compound to produce a positive ion. The ionizing compounds are produced by electron impact of ammonia, hydrogen, isobutane, methane, or water. The ionizing compounds produce positively charged molecules. The molecules do not fragment as much as in electron impact mass spectrometry. In negative ion mass spectrometry, electrons are absorbed by the sample molecules. Absorption may be accompanied by decomposition of the molecule into charged ions. Field ionization and field desorption mass spectrometry use high voltage electrostatic fields to produce ions. In field ionization mass spectrometry the sample in gas form is passed over a point or edge on which a potential of 107 or 108 volts per centimeter is maintained. Quantum tunneling by electrons in the gas to the high potential forms ions. In field desorption the sample molecules are absorbed, or deposited,on a surface. A strong electromagnetic field is applied to desorb the molecules as ions.

13-6. Detection and Identification of Residues.

a. Detecting and collecting the residue of explosives left after detonation is a difficult task. Detonation is a relatively complete reaction and the small amount of explosive left is scattered over a large area. The general destruction of the area also hampers the collection effort. The most likely places for the residue to be found is in the soil and other debris in the blast seat; wood, plastic, and other materials which can catch and hold the flying residue particles; and metal objects which were close to the point of detonation such as a part of the bomb. The debris from the explosion site is first microscopically examined. Many times black and smokeless powders can be identified by the shape and color of the residue. A vapor trace analyzer can be used on the debris to identify volatile explosives such as nitroglycerin. The vapor trace analyzer consists of a vapor preconcentrator and a gas chromatograph with an electron capture detector. The residue in the post detonation debris is of little chemical integrity. Solvent extraction is used to dissolve the residue for analysis. Solvent selection is important. Extraction of substances that could interfere with the subsequent analysis of the explosive is undesirable. Large amounts of solvent are used to extract even small amounts of explosive residue, so only analytical techniques which can handle trace amounts are used. The methods described in paragraphs 13-2 through 13-5 can be used. In addition X-ray diffraction patterns can be compared to patterns of known compounds for identification. Residues on hands and clothes are extracted and tested similarly.

b. Detection and identification can be made easier by adding a taggant to explosives. One taggant system which has been proposed consists of small layered particles which are laminated to increase the probability of surviving detonation. Each layer can be one of a number of colors. The sequence of colors can be decoded to determine the explosive and manufacturer. Magnetic particles and fluorescent indicators which respond to ultraviolet radiation are added to make the taggant particle easier to find after a detonation. Another taggant system which has been proposed uses layers of magnetic material with different Curie points. The Curie point is the temperature at which ferrimagnetism ceases.

13-7. Detection of Hidden Explosives.

a. Explosives can be detected using a variety of techniques. Many of the methods depend on vapor detection. Two methods, gas chromatography and mass spectrometry, have already been described. Electron capture detectors work on the same principle as the electron capture detector in gas chromatography which is discussed in paragraph 13-3d. In plasma chromatography the vapors are ionized at atmospheric pressure. An electrostatic field is applied to cause the ions to drift. Heavier ions will drift slower than lighter ones due to collisions with the inert gas at atmospheric pressure. In chemiluminescence, the reaction between ozone and NO, which produces luminescence, is used. In bioluminescence, microorganisms that luminesce in the presence of explosive vapors are used. For improved detection, two microorganisms may be used, one which gets brighter in the presence of the vapor while the other gets dimmer. In laser optoacoustic spectroscopy a modulated laser beam is tuned to the proper frequency to excite the vapors of explosives in a closed cell. The energy of the excited state is changed to translational energy through collisions with surrounding molecules. The translational energy is detected acoustically.

b. Animals, such as dogs, can also be used to detect explosive vapors. Vapor detection can be defeated with hermetic sealing. However, several methods are considered practical for detection of bulk explosives. The nuclear magnetic resonance techniques can be used. X-ray contrast can also be used. In this method gamma rays are passed through the material under test. The attenuation through the material is measured, then analyzed by a computer. Thermal neutron-activation can be used to detect bulk explosives. In this method a thermal neutron is absorbed by a nitrogen-14 nucleus to produce a nitrogen-1i 5 nucleus in an excited state. The nitrogen-1 5 nucleus will go to ground level by emission of a gamma ray. Neutron-nitrogen reactions can be differentiated from the neutron-other element reactions by the energy of the gamma rays produced. A system to make explosives easier to detect is to add a vapor taggant to the explosive material.

CHAPTER 14
PACKING, MARKING, STORAGE, AND SHIPMENT OF ENERGETIC MATERIALS

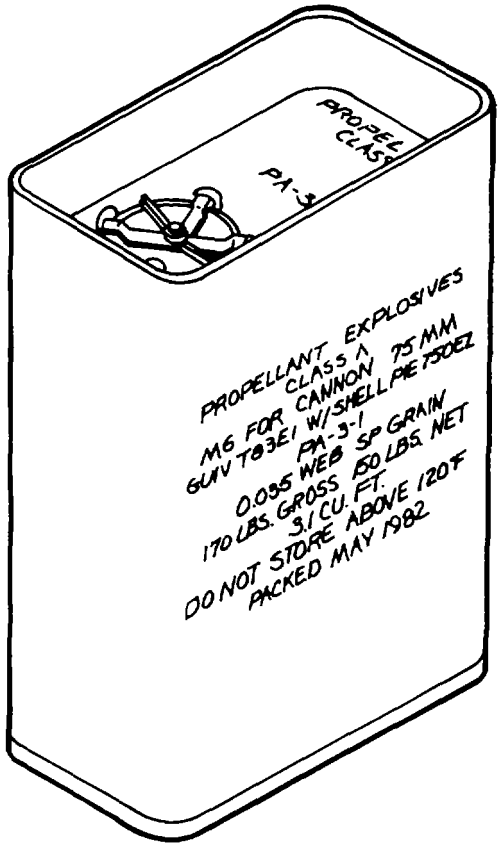
14-1. Introduction. The regulations governing the marking, packing, and shipping of military supplies are set forth in applicable Army regulations. These operations will also comply with Department of Transportation regulations. This chapter contains general regulations applying to the marking, packing, and shipping of explosives and ammunition. No live ammunition component that has been subjected to undue or abnormal forces for test purposes shall be offered for surface shipment by commercial carrier or be transported over public transportation systems by government conveyance except:

a. Items containing small quantities of explosive and constructed or packaged so that their explosive forces will be self-contained if they function.

b. Explosive items which both the testing agency and the project manager or appropriate major subordinate command agree in writing can be safely transported.

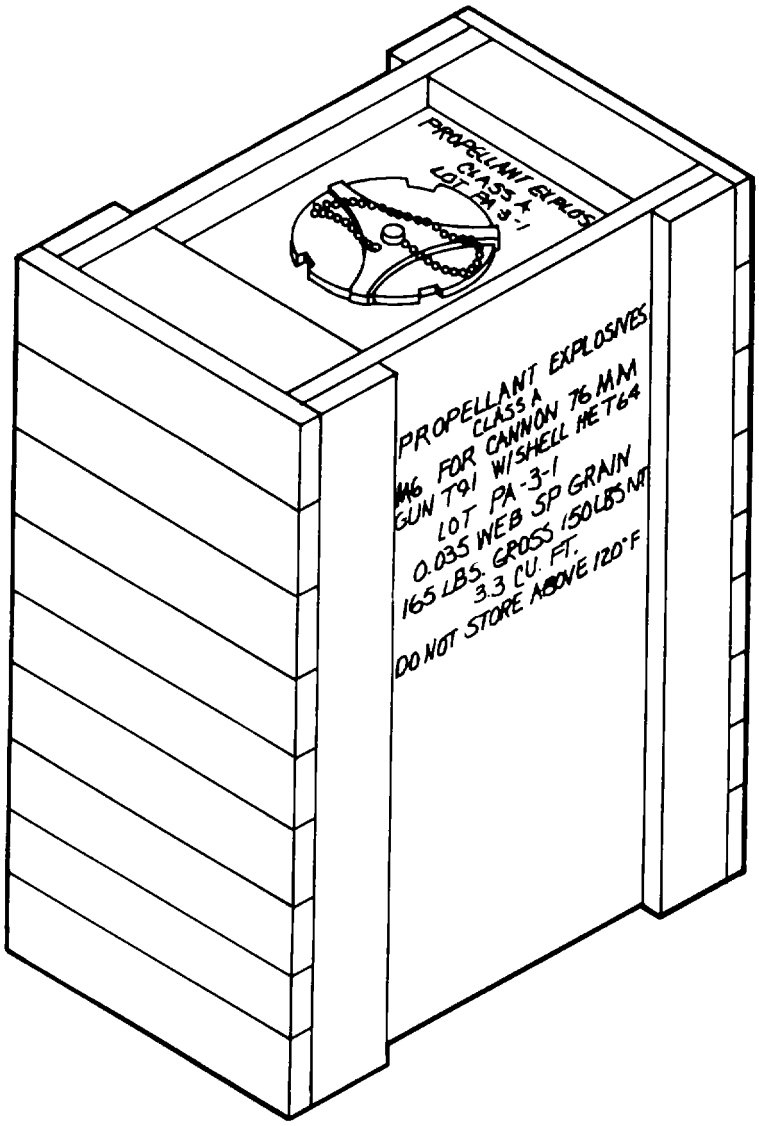
14-2. Packing.

a. *General.* Explosives are packaged to safely meet a wide variety of shipping and storage situations. Storage conditions may vary from the best possible coverage to no cover at all and from extremes in climatic conditions. Figures 14-1 through 14-7 area representative sample of explosives packaging.



ARR82-0062

Figure 14-1. Steel box for packing solid propellants, including marking.



ARR82-0063

Figure 14-2. Metal lined wood box for packing solid propellants, including markings.

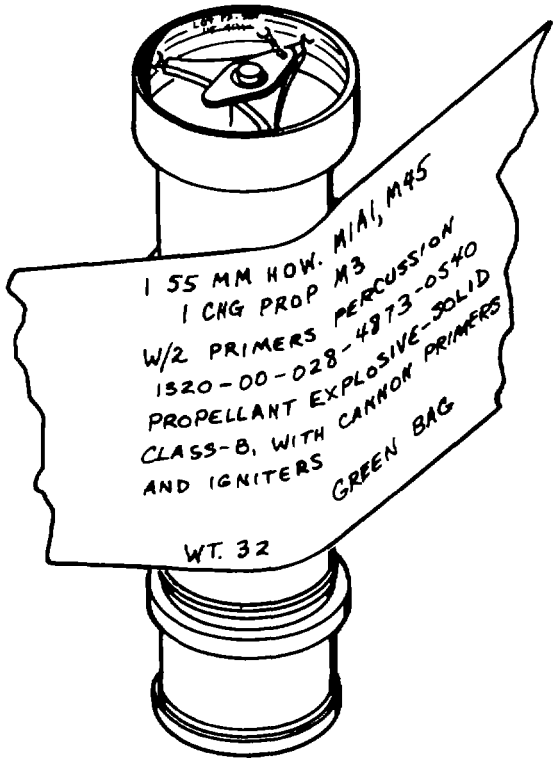
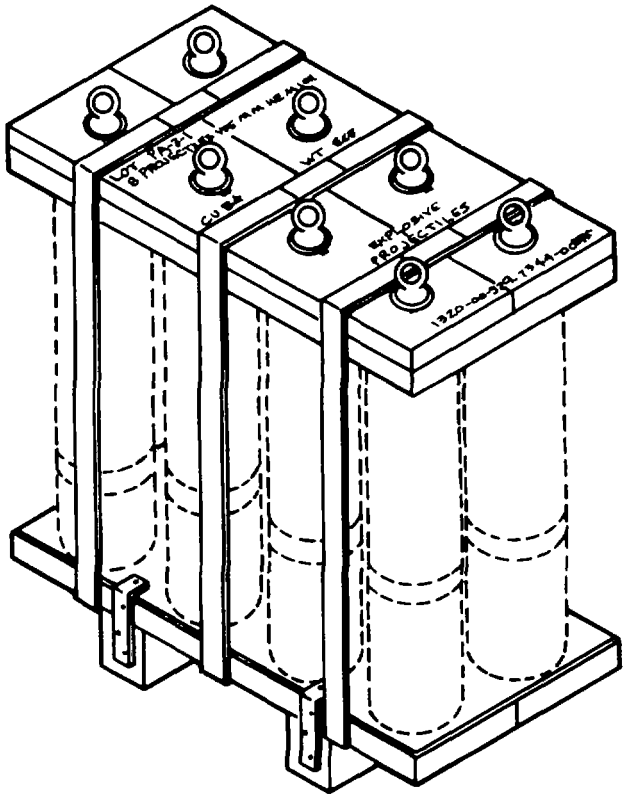
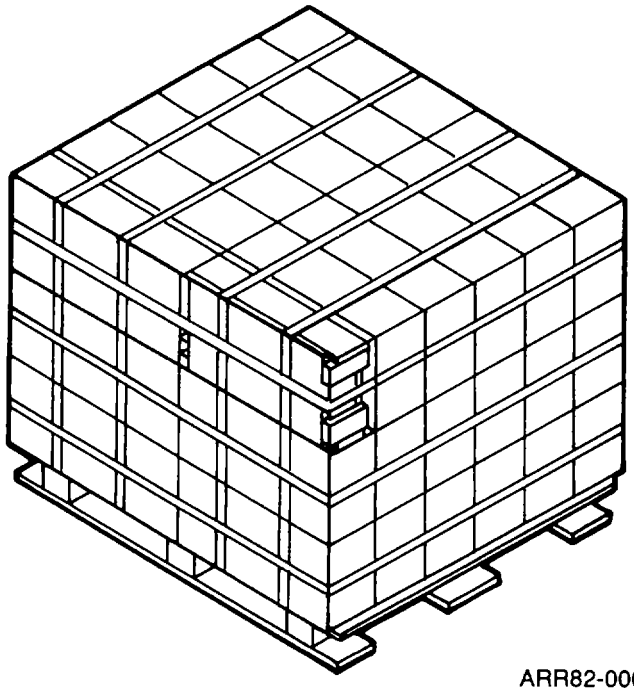


Figure 14-3. Metal containers for propelling charges, including marking.



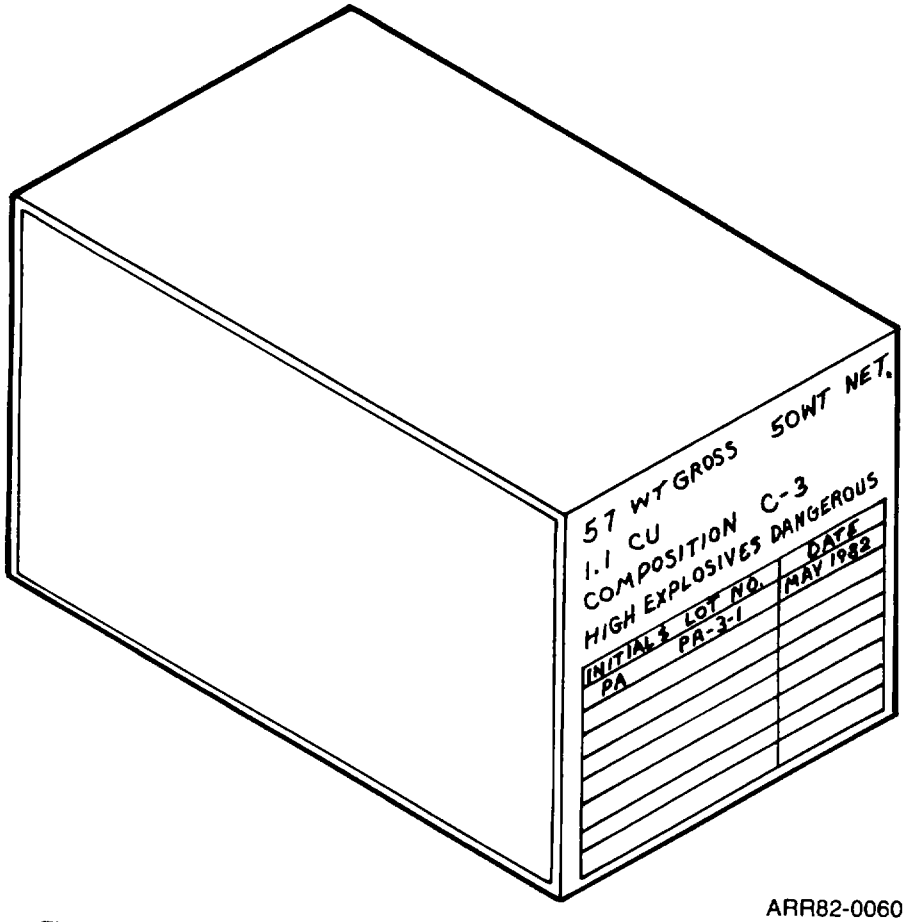
ARR82-0065

Figure 14-4. Palletized large caliber high explosive projectiles, including marking.



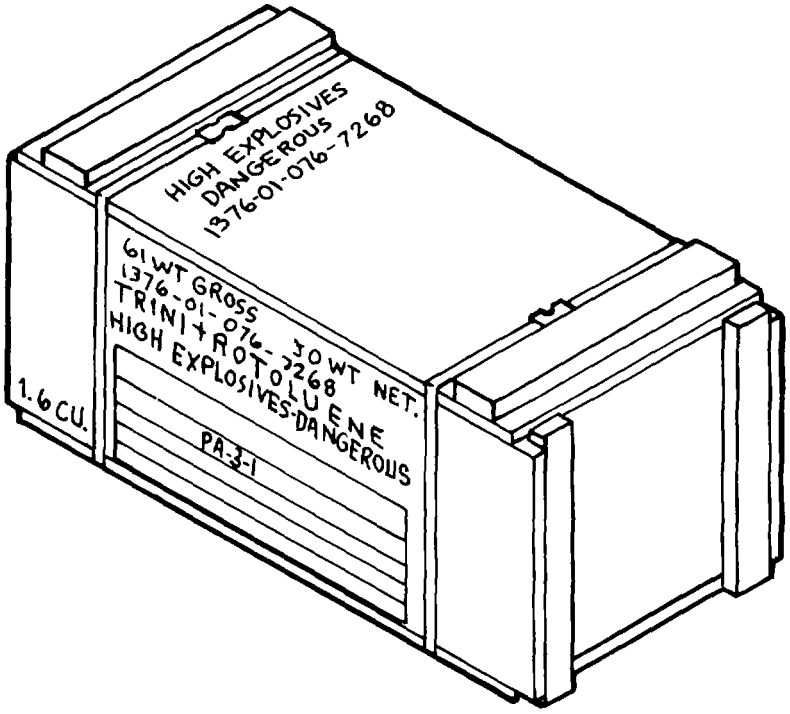
ARR82-0066

Figure 14-5. Palletized wood boxes containing explosives.



ARR82-0060

Figure 14-6. Carton for packing high explosives, including marking.



ARR82-0061

Figure 14-7. Wood box for packing high explosives, including marking.

b. *Containers.*

(1) Hazardous materials in bulk or liquid form must be transported in containers which will prevent leakage. Containers used in intraplant transportation and service storage of explosives and explosives mixtures such as initiating explosives, pyrotechnic compositions, and tracer materials should be made of material in the following order of preference: (a) Conductive rubber.

(b) Nonferrous metal-lined boxes without seams or rivet heads under which explosive dust can accumulate.

(c) Plastics (conductive type only).

(d) Paper-lined wood boxes.

(e) Fiber drums.

(2) Fiber drums or bulk explosives and propellants should be shipped only by motor carrier or trailer-on-flat car. Glass containers should not be used because of their fragility and severe missile hazard.

c. Black Powder Containers.

(1) Standard containers for black powder are built in accordance with drawings that meet DOT specifications.

(2) When black powder is shipped or received each container shall be inspected for holes and weak spots, particularly holes made by small nails which are visible only upon close examination. Damaged containers must not be repaired; the contents shall be transferred to new or serviceable containers.

(3) Empty black powder containers may be reused and may be transported empty provided they are clean. Empty metal containers which are not to be reused and will be salvaged shall be thoroughly washed inside with water.

(4) Black powder containers must be carefully opened. When it is necessary to open containers by puncturing, the operation will be conducted by remote control.

d. *Containers for Solid Propellants*.

(1) Solid propellants shall be packed in accordance with approved DARCOM drawings that comply with DOT regulation (fig 14-1).

(2) Double-based solid propellants, single perforated solid propellants, and all solid propellants with web thickness not greater than 0.4826 millimeters (0.019 inch) should not be packed in all-steel boxes. Metal lined wooden boxes (fig 14-2) should be used.

(3) Salvaged or deteriorated solid propellants should be shipped water wet.

e. Containers for Ammunition and Bulk High Explosives.

(1) Ammunition (fig 14-3, 14-4, and 14-5) and bulk high explosives (fig 14-6 and 14-7) shall be packed in accordance with approved DARCOM drawings that comply with DOT regulations.

(2) Containers used for packing bulk high explosives should be lined with strong cloth or paper bags or liners with cemented seams to prevent sifting.

14-3. Marking.

a. Each package of explosives is marked in accordance with pertinent drawings to provide positive identification (NSN, DODAC, nomenclature, lot number, and ICC marking as a minimum).

b. Whenever explosives or ammunition containers or ammunition and ammunition components are repainted, the new painting or marking shall correctly identify contents of items. The marking of empty or inert loaded ammunition items for display purposes is governed by the provisions of AR 385-65.

c. Explosives, ammunition, and loaded ammunition components obtained from salvage operations and material which has lost its identification markings shall be clearly marked to show the explosive nature of the material. Explosive material or items which cannot be definitely identified as to their explosive nature should be disposed of by technically trained personnel in accordance with the provisions of DARCOM-R 385-100.

d. See figures 14-1 through 14-7 for a representative sample of markings required on explosives packaging.

14-4. Storage of Explosives and Ammunition.

a. *General.* The types of existing magazines listed below are considered standard for the storage of the types of items specified. New storage magazines should be of the earth covered, corrugated steel, or reinforced concrete arch type.

b. *Magazines.*

(1) Earth covered magazines. These include igloo, steel arch, Stradley, special type, hillside, and subsurface type magazines. Earth covered magazines are preferred for the storage of all items of ammunition or explosives.

(2) Standard ammunition magazines (commonly called "standard magazines"), classed as above ground magazines. These magazines were designed for the storage of fixed rounds or separate loading projectiles. For future use, they should be restricted to the storage of Classes (04) 1.2, (08) 1.2, (12) 1.2, 1.3, and 1.4 materials (excluding rockets and rocket motors). The magazines measure 15.7 by 66.6 meters (51 feet 7 inches by 218 feet 8 inches), are usually spaced 91.5 meters (300 feet) apart, and have concrete foundation walls and piers, hollow-tile walls, steel frames, and concrete floors. The storage capacity of the magazines is not stated in definite figures since the number of items which can be stored is regulated by the appropriate quantity-distance tables.

(3) High explosives and black powder magazines, classed as above ground magazines. These magazines were designed for the storage of bulk explosives such as black powder, TNT, tetryl, and explosive D and may be used for this purpose where more desirable storage space cannot be obtained. They are 8.4 meters (27 feet 6 inches) wide and 13.2 meters (43 feet 4 inches) long and are usually spaced 243.8 meters (800 feet) apart. They have concrete foundation walls and piers, hollow tile walls filled with sand, steel frames, and concrete floors covered with sparkproof mastic or the equivalent. The magazines were originally designed for the storage of 1 13,400 kilograms (250,000 pounds) of explosives, but in order to assure adequate aisle space for inspection and shipping and convenient height of piles, the amount of storage is usually limited to approximately 45,360 kilograms (100,000 pounds).

(4) Primer and fuze magazines, classed as above ground magazines. These magazines were designed for storing primers, primer detonators, adapters and boosters, and fuzes of all types. In the future when it is necessary to use magazines of this type, they should be restricted to the storage of Classes (04) 1.2, 1.3 (except rockets and rocket motors), and 1.4 ammunition and explosives. The magazines are 8.4 meters (27 feet 6 inches) wide, 13.2 meters (43 feet 4 inches) long and are usually spaced 91.5 to 121.9 meters (300 to 400 feet) apart. With respect to construction details, they are similar to high explosive and black powder magazines except the hollow tile walls are not sand filled and the floor is not covered with spark proof mastic.

(5) Service magazines and service storage buildings. These buildings are used for intermediate storage of the minimum amount of explosives necessary for safe and efficient manufacturing or processing operations. Construction details of such magazines should specify the use of fire-resistant materials and/or fire-resistive construction.

(6) Other structures. Structures not of approved magazine type shall not be used for the storage of explosives and ammunition except when authorized by the Commander, HQ DARCOM, Attn: DRCSF.

c. *Temperature Control.*

(1) Sudden changes in temperature may damage airtight containers or may result in excessive condensation of moisture. If the temperature in a magazine exceeds 37.80C (100°F) for a period of more than 24 hours, the magazine should be cooled by wetting the exterior of the building with water or by opening the doors and ventilators after sunset and closing them in the morning. If these methods do not prove effective in lowering the temperature, the Commander shall decide whether the materials should be removed to some other magazine.

(2) Storage magazines, in general, should not be provided with heat. Exception is made in the case of magazines where heating may be necessary to prevent condensation of moisture, to maintain constant temperature, or other reasons. If steam or hot water coils are used to heat a magazine, they must be so arranged that explosives material cannot come in contact with the coils. The coils must be kept clean.

d. *Magazine Operational Regulations*. The following regulations shall be complied with where ammunition and explosives are stored:

(1) Instructions as printed on magazine placards, DA Label 85, must be posted on or near each door of the magazine so that they are visible when work is being done in the magazine.

(2) Loose components of ammunition, packing materials, conveyors, skids, dunnage, empty boxes, and other similar material shall not be stored in magazines containing ammunition or explosives.

(3) Vegetation around all ammunition and explosives storage locations shall be controlled.

(4) Doors and locks must be kept in good working order. Magazines shall be locked at all times except when permitted operations are in progress in the magazine and as provided for in paragraph 14-4c(1). A crew must not be permitted to work in a position in a magazine which requires passing the work aisle or position of a second crew to reach an exit. The number of crews shall not exceed the number of exits. Two or more doors must be unlocked and open when personnel work in magazines having more than one door.

(5) Flammable liquids, except when used as the chemical filler of a munition or as a prepackaged storable liquid propellant, shall not be stored in magazines containing explosives.

(6) Except when required for security purposes, service magazines within an operating line need not be locked during shift operations. These magazines must be locked whenever the operating line is shut down; i.e., nights, weekends, and holidays.

e. *Stacking.*

(1) Ammunition and explosives shall be stored in containers as prescribed by approved DARCOM drawings and specifications and shall be stacked and arranged in a magazine in accordance with instructions set forth in Army regulations and approved DARCOM drawings and directives. Explosives or ammunition in stacks shall be grouped and identified according to lots. When military explosives or ammunition are not packed in accordance with approved drawings and specifications, they must be stored in accordance with special instructions from the Commander DARCOM, ATTN: DRCSF. General rules set forth in paragraphs (2). and (3) below should be followed in the absence of applicable storage drawings.

(2) Methods used for stacking must provide for good ventilation to all parts of the stack. Adequate dunnage shall be used for this purpose.

(3) Aisles shall be maintained so that units in each stack may be inspected, inventoried, and removed for shipment or surveillance tests. Block storage is permitted, provided adequate ventilation of stacks exists. Unobstructed aisles shall be maintained to permit rapid egress of personnel.

(4) Only one light box, pallet, or unit should be allowed per lot in storage. A light box, pallet, or unit is defined as a box, pallet, or unit which contains less than the normal quantity or count. Packaging and marking shall be in accordance with approved drawings and regulations. Light units shall be readily visible and immediately accessible when stacked in storage. Light units might be painted white.

f. *Permitted Open Storage.*

(1) Open storage of ammunition/explosives and limited material will not be used in lieu of covered storage employing standard facilities and/or methods.

(2) When circumstances dictate that open storage must be utilized for storage of Army owned material, the storing installation will submit a request for waiver in accordance with DARCOM-R 385-100. Requests involving material owned by another service will be forwarded through the same channel (through HQ DARCOM, ATTN: DRCSF-E) to the owning service.

(3) Bulk solid propellants, bagged propelling charges, pyrotechnics, bulk high explosives, and critical items shall not be placed in open storage.

g. *Open Storage Sites.*

(1) Sites for open storage shall be separated from magazines, other facilities, and each other in accordance with the requirements of Chapter 12.

(2) The storage sites shall be level, well drained, and free from readily ignitable and flammable materials. The supporting timbers or platform upon which the ammunition is stored shall be well constructed to prevent falling, sagging, and shifting of the ammunition. In order to assure stack stability and free circulation of air, not less than three inches of dunnage should be used between the bottom of the stack and the earth floor. Provisions should also be made for circulation of air through stacks. Non-flammable or fire-resistant, waterproof, overhead covers should be provided for all ammunition containing solid propellants, torpex, tritonal, minol, or chemical agents since each of these materials may be adversely affected by exposure to the elements. An air space of not less than .45 meter (18 inches) should be maintained between the top of the stack and the cover. If adequate ventilation is assured, overhead covers are also desirable for outdoor stacks of bombs and shells. Sides of covered stacks also may be protected by non-flammable or fire-resistant, waterproof covers provided air space is maintained between the cover and the ammunition.

(3) Frequent inspections shall be made to detect sagging piles and accumulations of trash between or under stacks.

(4) If revetments are to be provided around open storage sites, they must comply with the requirements of Chapter 12. Stacks of ammunition must be kept at least 0.61 meter (two feet) from the base of the revetment and at least 0.31 meter (one foot) below the top of the revetment.

(5) Excess dunnage should not be stored between open sites and magazines nor between magazines. Excess dunnage storage sites should comply with applicable quantity-distance requirements except that during open storage operations, service supplies of dunnage may be located not closer than 15.3 meters (50 feet) from the stack being processed.

(6) Suitable types of firefighting equipment and fire symbols should be provided.

h. Special Requirements for Open Storage.

(1) Sites between earth covered magazines. Sites may be located midway between adjacent earth covered magazines which are 121.9 meters (400 feet) apart, provided the sites are barricaded and are separated from the barricaded sides of the nearest magazine by 56.4 meters (185 feet). Ammunition in such sites should not be stored beyond lines drawn through the fronts and backs of magazines in the same row. Barricading does not reduce the required inhabited building or public traffic route distances. The storage of Class 1.2 between earth covered magazines is not desirable and should be resorted to only when necessary. Sites containing Class 1.2 may not be located closer than the fragment distance from other open sites. The limitations of the quantity-distances listed in table 14-1 also are applicable.

Table 14-1. Special Requirements for Open Storage Between Earth Cover Magazines

Hazard class and division		Maximum kilograms (pounds) of HE		Minimum intersite distance meters (feet)		
	1.4		No limit		(400)	
(04)	1.2	45,360	(100,000)	121.9	(400)	
(08)	1.2	45,360	(100,000)	243.8	(800)	
(12)	1.2	45,360	(100,000)	365.7	(1,200)	
(18)	1.2	45,360	(100,000)	548.6	(1,800)	
	1.1	45,360	(100,000)	121.9	(400)	or fragment distance (if appropriate) whichever is greater.

(2) Sites not between earth covered magazines. Sites containing Class 1.2 shall not be stored closer than fragment distance from other sites. No open storage site shall be located within 365.7 meters (1,200 feet) of above ground magazines. The limitations of the quantity-distances listed in table 14-2 also are applicable.

Table 14-2. Special Requirements for Open Storage Between Magazines That Are Not Earth Covered

Hazard class and division	Maximum kilograms (pounds) of HE		Minimum intersite distance meters (feet)		
1.4	No limit		30.5	(100)	
(04) 1.2	No limit		121.9	(400)	
(08) 1.2	226,800	(500,000)	243.8	(800)	
(12) 1.2	226,800	(500,000)	365.7	(1,200)	
(18) 1.2	45,360	(100,000)	548.6	(1,800)	
1.1	45,360	(100,000)	(280)	(barricaded)	or fragment
	45,360	(100,000) 155.4	(510)	(unbarricaded)	distance (if
	113,400	(250,000) 115.8	(380)	(barricaded)	appropriate)
	113,400	(250,000) 211.8	(695)	(unbarricaded)	whichever is greater

(3) General. Inhabited building distance and public traffic route distance shall be maintained around open storage sites as specified in Chapter 12.

i. Storage of Bulk Initiating Explosives. Bulk initiating explosives must not be stored dry and shall not be exposed to the direct rays of the sun. Glazed earthenware crocks of ample size to hold the double bag of material with covers of the plastic cap type to prevent evaporation and eliminate friction or abrasion when removed are used for normal storage. Proper selection and use of covers is required to prevent friction and pinch points. If long term storage in shipping containers is contemplated, the container must be equipped with a cover having a port for observation of the level of liquid therein. The viewing port must be covered with a transparent plastic which is known to be compatible with the initiating explosives being stored. As an expedient only, bulk initiating explosives may be stored in shipping containers that are not so equipped, provided they are stored in frostproof, earth covered magazines, with containers on end, only one tier high, and with passageways for inspection and handling. Bags of initiating explosives in storage containers must be under distilled water. Alcohol may be added to the distilled water to prevent freezing.

j. Solid Propellants. Propellants shall not be stored or shipped in damaged containers. When leaking containers are discovered, an examination of the contents shall be made for the nitrous odor of decomposing propellant. If any such condition is observed, the propellant shall be segregated or properly disposed of. Propellants and propelling charges in containers should be stored so that they can be readily inspected. They shall not be exposed to the direct rays of the sun.

k. Small Arms Ammunition. Boxed small arms ammunition shall not be used as barricades or dividing walls between stacks of other types of ammunition.

l. Separate-Loading Ammunition, HE Loaded Except Explosive D.

(1) Separate-loading projectiles must be handled with care. They shall not be stored without fuze-well closing plugs. Metal dunnage should be used where practicable.

(2) Class (18) 1.2 quantity-distances are the minimum acceptable for Class (18) 1.2 items, regardless of the quantities of the HE involved. For Class (18) 1.2 separate-loading projectiles, storage must comply with DARCOM Drawing 19-48-4102-1-2-14PE1001 in order to limit distance requirements to those prescribed by the Class (18) 1.2 quantity-distance table. If those projectiles are equipped with core-recessed lifting plugs, the Class 1.1 quantity-distance table applies when the total quantity of HE involved exceeds 6,804 kilograms (15,000 pounds) in above ground magazines, even if storage complies with DARCOM Drawing 19-48-4102-1-2-14PE1001.

m. Separate-Loading Ammunition Explosive D Loaded, Class (12) 1.2. Except where permanent block type storage methods are used, this type of projectile may be stored with distances between stacks not more than that required to permit inspections.

n. Fixed and Semi-Fixed Ammunition. Boxed fixed and semi-fixed ammunition shall not be used as barricades or dividing walls between stacks of other types of ammunition.

o. Rockets and Rocket Motors.

(1) Whenever practicable, rockets and rocket motors that are in a propulsive state should be stored nose down. Small rockets and missiles may be stored in standard earth covered magazines without regard to direction in which they are pointed except that they will not be pointed toward the door of the magazine. If not in a propulsive state, any rocket, rocket motor, or missile may be stored in any magazine without regard to the direction in which they are pointed.

(2) In above ground magazines where nose down storage is not practicable, items (in a propulsive state) shall be pointed in the direction which offers the least exposure to personnel and property in the event of fire or explosion.

(3) Rockets should be stored in a dry, cool magazine out of the direct rays of the sun. They should not be stored in locations where temperatures exceed 49°C (120°F). Prolonged exposure of rocket ammunition to either high or low temperatures may increase the normal rate of deterioration or render the motors more susceptible to ignition if subsequently handled improperly.

14-5. Shipment of Explosives and Ammunition.

a. *General*. Explosives and ammunition are routinely shipped via all common modes of transportation, i.e., railroad, truck, ships, and aircraft. However, due to the commodities hazardous nature each of the transportation modes rigidly adheres to its own specific set of regulations.

b. *Railroad Transportation*. The operation of railroads within a DARCOM establishment shall be in accordance with applicable current directives, particularly TM 55-200, Railroad Operating Rules and this regulation.

(1) Specifications for equipment. The regulations of the Department of Transportation, the Federal Railroad Administration, and the Association of American Railroads pertaining to safety devices, safety guards, design of equipment, etc. are mandatory for railway equipment involved in transporting materials between establishments. The same regulations should be followed for inspection, maintenance, and operation of railroad equipment within an installation.

(2) Transportation of hazardous materials.

(a) In addition to the requirements of other parts of this section, the rules in subparagraphs (b) through (i) below shall be followed.

(b) When cars containing explosives or other hazardous materials are received at the installation or held in yards, precautions must be taken to prevent accidents, particularly at night. These precautions must include provisions for quickly removing and isolating the cars in case of fire.

(c) Cars loaded with hazardous materials must be loaded and placarded as prescribed by Department of Transportation regulations before being offered for transportation. The carrying of hazardous materials on locomotives or other self-propelled rail vehicles is prohibited.

(d) Before cars are moved by a locomotive, the air brake hose must be coupled and tested to assure that the air brakes are in proper working condition and the car doors shall be closed.

(e) Empty cars shall not be removed from warehouses, magazines, buildings, or loading docks until all warning placards have been removed.

(f) Special care must be taken to avoid rough handling of cars. Cars must not be "cut off" while in motion and must be coupled carefully to avoid unnecessary shocks. Other cars must not be "cut off" and allowed to strike a car containing explosives. Cars must be so placed in yards or on sidings that they will be subject to a minimum of handling and be readily removed from danger of fire. Such cars must not be placed under bridges or in or alongside passenger sheds of station, and where avoidable, engines on parallel tracks should not be allowed to stand opposite or near them.

(g) "Dropping," "humping," "kicking," or the use of the flying switch is prohibited.

(h) Adequate measures such as guarding, patrolling, and safety inspection must be provided at all times. All such activity should be under positive administrative controls.

(i) Fire symbols or DOT placards shall be placed on each railroad car while transporting explosives or ammunition within a DARCOM establishment in order to provide a ready means of identifying the potential hazard should a fire occur.

(3) Placarded railcars. Placards shall be applied in accordance with DOT regulations to railcars transporting hazardous materials. Ammunition and explosives shall be loaded and braced in accordance with approved drawings.

(4) Car inspection. A car must not be loaded with any DOT Class A explosives unless it has been thoroughly inspected by a qualified employee of the carrier who shall certify that its condition conforms to DOT regulations. After a certified car has been furnished by the carrier, the shipper or his authorized employee must, before commencing the loading of any such car, inspect the interior thereof and after loading, certify to its proper condition. A certificate will be completed and signed where applicable. Shipments of Class B explosives may be loaded in a closed car or container car which is in good condition, into which sparks cannot enter, and with roof not in danger of taking fire through unprotected decayed wood. Wood floored cars must be equipped with spark shields. Such cars do not require a car certificate but must be placarded in accordance with paragraph 14-5b(3) above.

(5) Car certificates. The car certificate printed on strong tag board measuring 177.8 millimeters x 177.8 millimeters (7 by 7 inches) or 152.4 by 203.2 millimeters (6 by 8 inches) must be duly executed in triplicate. The original copy must be filed by the carrier at the forwarding station in a separate file and the other two must be attached to the car, one to each outer side on a fixed placard board or as otherwise provided.

(6) Leaking packages. Constant alertness must be maintained to detect, through characteristic odors, the leakage of hazardous materials from faulty packages. Leaking packages should be removed from cases and repaired, or if in tank cars, the contents should be transferred. If artificial light is necessary, only electric lights approved for the hazard involved shall be used. Leaking tank cars containing compressed gases shall be switched to a location distant from habitation and highways and proper action taken for transferring contents under competent supervision. Cars containing leaking packages or leaking tank cars must be protected to prevent ignition of liquid or vapors by flame from inspectors' lanterns or torches, burning fuses, switch lights, switch thawing flames, fires on side of track, or from other sources. All unnecessary movement of a leaking car discovered in transit must cease until the unsafe condition is remedied.

(7) Car loading of items containing ammunition and explosives. Loading methods prescribed by DARCOM drawings shall be followed for the loading and bracing of railway car shipments of military explosives and ammunition. The packages should be placed in position with no more force than is needed to secure a compact load and to prevent shifting and damage en route. Excessive or violent use of mauls shall not be permitted when positioning packages.

(8) Sealing cars containing explosives and ammunition. In addition to any other seals which may be used, cars containing explosives or ammunition shall be sealed. A cable seal lock will be used to secure car doors plus an upper rail lock. Serial numbers of seals will be placed on GBL (DOD 5100.76M and AR 55-355, Chapter 13). If the seal is not in place when the car is received, the car shall be treated as suspicious and shall be inspected. See AR 55-38 for instructions on recording details when shortage, pilferage, or apparent theft is involved.

(9) Inspection of cars before unloading.

(a) Rail cars containing explosives and ammunition entering a DARCOM establishment must be inspected. This inspection comprises the examination of the outside and under side of each car for damage such as defective brakes, couplings, wheel flanges, etc; to detect unauthorized and suspicious articles; to check correctness of individual car numbers and seal numbers against bills of lading. When the probability of sabotage is remote, such inspections may be accomplished from ground level without the aid of an inspection pit to discover unsafe structural and mechanical deficiencies of the car. During periods of emergency when sabotage may be attempted, and also to aid in the rapid inspection and movement of cars, an inspection pit should be provided.

(b) Cars of ammunition or explosives on which foreign and suspicious articles have been secreted or attached outside or underneath the car, or cars which show a defect that might affect the installation or contents of the car, shall be removed to the suspect car siding for additional inspection. In addition, during the times of national emergency, cars on which the seal numbers do not correspond to those shown on the bill of lading shall be treated as suspect cars and should be removed to the suspect car siding for additional inspection.

(c) Cars which satisfactorily pass the inspection outlined above may be considered reasonably safe but care must be exercised in breaking car seals and opening car doors because of the possibility of damage or shifting lading, leaking containers, etc. When the quantity and class of ammunition present in the classification yard does not exceed that permitted by the appropriate quantity-distance table, based on distance to adjacent targets, cars may be opened for inspection at that point, otherwise interior inspection should be accomplished after the cars have been spotted at the unloading point.

(10) Inspection of cars after unloading. Cars in which explosives or ammunition are received shall be inspected after unloading to see that they are clean and free from loose explosives or other flammable materials, and that the placards and car certificates are removed.

Explosives sweepings shall be destroyed.

(11) Damaged shipment. Any shipment received in a damaged condition as a result of inadequate or improper blocking and bracing or not loaded in accordance with appropriate DARCOM drawings shall be reported on Discrepancy Shipment Report (SF 361) in accordance with AR 55-38. If the damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

c. Motor Vehicle Transportation. The operation of motor vehicles within a DARCOM installation shall be in accordance with this and other applicable current regulations.

(1) Motor vehicle safety program. Current regulations, particularly AR 385-10, Army Safety Program, require the institution of a motor vehicle safety program as part of the overall safety program of a DARCOM installation. AR 385-55, Prevention of Army Motor Vehicle Accidents, contains detailed information for inclusion in such a program. Oth,r pertinent regulations are AR 55-162, AR 55-203, AR 55-355, AR 55-357, AR 735-11-2, and AR 55-38.

(2) Motor vehicle shipment regulations. Motor vehicle shipments on public highways are governed by the Department of Transportation regulations. All motor vehicle shipments from a DARCOM installation shall comply in full with the applicable portions of DOT, state, and municipal regulations except as provided for in these regulations. Before any motor vehicle designated for movement over public highways may be loaded with ammunition or explosives (DOT Class A or B) and other dangerous articles, as specified in chapter 216, Section II, AR 55-355, the vehicle must be inspected and approved by a qualified inspector for compliance with AR 55-355 (DD Form 626) Motor Vehicle Inspection. After loading, lading must be inspected and approved. Driver selection, training, etc., for intraplant shipping and for operation of government owned trucks on public highways shall be in accordance with pertinent requirements of 49 C.F.R. Parts 390-397, Federal Motor Carrier Safety Regulations, FM 55-30, Army Transportation, Units and Operations, and FM 21-305, Manual for the Wheeled Vehicle Driver.

(3) Motor vehicle for explosives shipment. Cargo type trucks and truck-tractor drawn semitrailer vans are the preferred means for transporting ammunition, explosives, and other hazardous material. Other types of trailers should not be used by DARCOM installations for this purpose except where the material is sufficiently large to make handling by vans impractical (this restriction need not apply to licensed common carriers and contract equipment). Equipment used for transporting ammunition, explosives, and other hazardous material must meet the following requirements and these should be supplemented by local regulations as deemed necessary by the commander.

(a) Loading methods prescribed by DARCOM drawings shall be followed for the loading and bracing of motor vehicle shipments of military explosives and ammunition. The packages should be placed in position with no more force than is needed to secure a compact load and to prevent shifting and damage en route. Excessive or violent use of mauls shall not be permitted when positioning packages.

(b) Special precautions must be taken to avoid ignition of the material by the exhausts of automotive vehicles.

(c) The lighting system shall be electric. Batteries and wiring shall be so located that they will not come into contact with containers of explosives, ammunition, or other hazardous material. If exposed explosives or flammable vapors are encountered in a vehicle, only approved type portable lights should be permitted (certified by a nationally recognized testing organization for the specific hazardous location as defined by the National Electric Code).

(d) The interior of the truck body shall have all exposed ferrous metal covered with nonsparking material when transporting scrap and bulk explosives in containers which may be damaged and explosives become exposed. If the explosives transported consist of ammunition or explosives packaged for shipment in accordance with DOT specifications, it will not be necessary to cover the ferrous metal. Open body vehicles other than the flatbed trailer type used to transport large items such as rockets or missiles must have sides that are strongly made and securely fastened so that the items are safely retained. Where a top is required, it should be of a noncombustible or flame-proof material. Whenever tarpaulins are used for covering explosives, they will be secured by means of rope or tiedowns. Nails will not be used to fasten protective tarpaulins.

(e) All trucks (government and commercial) destined for offpost shipment over public highways shall be equipped with one (1) Class 1 O-BC rated portable fire extinguisher when transporting DOT Class A, B, or C explosives. Government motor vehicles involved only in on-post shipments shall be equipped, as a minimum, with two (2) Class 1-BC rated portable fire extinguishers; one mounted outside the cab on the driver's side of the vehicle and the other inside the cab. If government vehicles are equipped with an interior carbon dioxide or dry powder flooding device, only one extinguisher is required and should be mounted on the outside of the cab on the driver's side.

(f) Red lights are not permitted on the front of vehicles transporting explosives and ammunition.

(g) Trucks fueled with LP gas shall not be used to transport ammunition and explosives in ammunition areas.

(4) Inspection of vehicles. Government owned motor vehicles used for transportation of hazardous materials shall be inspected at frequent intervals by a competent person to see that mechanical condition and safety devices are in good working order and that oil and motor pans under engines are clean. Because of vehicle usage, this requirement is over and above the inspection requirements of TM 38-750. Daily inspection shall be made by operators to determine that: (a) Fire extinguishers are serviceable.

(b) Electric wiring is in good condition and properly attached.

(c) Fuel tank and piping are secure and not leaking.

(d) Brakes, steering, and other equipment are in good condition.

(e) The exhaust system is not exposed to accumulations of grease, oil, gasoline, or other fuels, and has ample clearance from fuel lines and other combustible materials.

(5) Mixed loading. The types of hazardous materials that may be loaded and transported together over public highways are established in 49 CFR 177.835(c) and 177.848. These DOT requirements shall be complied with for shipments over public highways.

(6) Instruction to drivers. Before motor vehicles loaded with hazardous materials leave a DARCOM establishment, drivers shall be informed of the nature of their cargo and methods of fighting fires involving the truck or its cargo. DD Form 836 (Special Instructions for Motor Vehicle Drivers) will be completed in accordance with the requirements of AR 55-355 and furnished such drivers. The provisions of TB 38572, Nuclear Weapons Fire Fighting Procedures, shall be applied, when applicable.

(7) Inspection and movement of incoming shipments.

(a) Motor vehicles loaded with explosives, ammunition, or other hazardous materiel shall be carefully inspected by a competent person at a designated inspection station in accordance with AR 55-355 using DD Form 626. The inspection station should be located remotely from hazardous and populated areas.

(b) When inspection reveals that an incoming tractor is in an unsatisfactory condition, it should be disconnected from the trailer (at the inspection station) and moved to a position where it will not endanger any explosives.

(c) When inspection reveals that the trailer or its load is in an unsatisfactory condition, it shall be removed to a location which is at least inhabited building distance (not less than fragment distance for fragment producing items) for the material involved from inert and administration areas, hazardous locations, and the installation boundary. At this location, correction of unsatisfactory conditions shall be accomplished prior to movement to the destination of the vehicle within the installation. The route when moving from the inspection station to the isolated locations, insofar as possible, should be removed from built-up areas and areas where personnel concentrations are high.

(d) Vehicles which cannot be dispatched immediately to points where they are to be unloaded may be moved to a holding yard which shall be sited in accordance with paragraph 12-111.

(e) Incoming or outgoing ammunition and explosives loaded trailers that cannot be exchanged directly between the carrier and the DARCOM installation may be moved in to interchange yard. Quantity-distance provisions do not apply provided the trailers are moved expeditiously from the interchange yard. At least 3.048 meters (10 feet) separation should be maintained between trailers in an interchange yard.

(8) Damaged shipments. Any shipments received in a damaged condition as a result of inadequate or improper blocking and bracing or not being loaded in accordance with appropriate DARCOM drawings shall be reported on Discrepancy Shipment Report (SF 361) in accordance with AR 55-38. If the damage was due to improper preservation, packaging, or packing SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

d. *Air Transportation.* The carriage of ammunition, explosives, and other hazardous materials by civil aircraft is regulated by the DOT. See 49 CFR 106-178, particularly Part 175. Criteria for the preparation and carriage of hazardous materials on military aircraft and certain Department of Defense contract airlift operations conducted under DOT Exemption 7573 are contained in TM 38-250.

(1) Military aircraft operating regulations.

(a) Operation of military aircraft shall be in accordance with requirements outlined in the applicable flight envelope, Army and/or Air Force regulations, and as further required by locally established regulations.

(b) If an aircraft carrying dangerous articles makes a forced landing and only minor repairs are necessary, the cargo need not be unloaded but repairs should be accomplished at a location separated from dissimilar exposures and other aircraft by the appropriate inhabited building distance for the cargo aboard. For major repairs, the plane shall be unloaded and the cargo stored in accordance with appropriate quantity-distance requirements. Appropriate protection should be afforded the cargo during inclement weather. If a landing is made for refueling purposes only, the cargo need not be unloaded. Refueling shall be accomplished at a location suitable for the performance of minor repairs as described above.

(c) Prior to take off or landing, the pilot must contact the tower for taxi, take off, or landing and parking instructions. The pilot shall, when requesting instructions, make known the contents of the cargo and shall request priority for his aircraft.

(d) When an aircraft containing ammunition or explosives is parked on a DARCOM installation in a designated, restricted, posted, and traffic controlled explosives parking or loading and unloading area, fire symbols will be posted at all normal approaches to the designated area. If parked in an area on a DARCOM installation which is not a designated, restricted, posted, and traffic controlled explosives parking or loading and unloading area, fire symbols will be placed at the nose, tail, and each side of the aircraft. Where the height of the aircraft does not readily permit attaching the fire symbols to the aircraft, the fire symbols may be mounted on stands approximately 1.5 meters (five feet) in height positioned adjacent to the aircraft where they are visible at long range. At other DOD installations and at non-DOD installations, placarding will be in accordance with the requirements of TM 38-250 and the requirements of the host installation.

(2) Permissible air shipments. Hazardous materials that may be shipped by civil air are identified in 49 CFR 172.101 along with the maximum net quantities per package and in Chapter 4 of TM 38-250 for shipments by military aircraft. External or internal transportation of electrically initiated explosive loaded items or components by helicopter will not be permitted without prior approval from the Commander, DARCOM. Packages must conform to the requirements of DOT regulations. Dangerous articles and other cargo must be firmly lashed to the aircraft structure or otherwise secured to prevent shifting in flight. Signaling devices, equipment necessary to promote safety in operations, small arms equipment in moderate quantities for personal use, and other items as permitted in Title 49 CFR part 175.10 may be carried without complying with the above requirements. Dangerous articles must be placed in a baggage compartment inaccessible to passengers during flight.

(3) Loading and unloading aircraft.

(a) Prior to loading or unloading ammunition, explosives, and other hazardous materials, the aircraft shall be electrically grounded so that the resistance to ground does not exceed 10,000 ohms.

(b) When loading or unloading aircraft containing ammunition or explosives, placards and fire symbols will be displayed as indicated in paragraph 14-5d(1)(d).

(c) Loading and unloading shall be done in accordance with quantity-distance requirements (para 14-5d(1)(b).

(d) All ignition switches must be in the off position.

(e) Front and rear wheel chocks shall be in place.

(f) Military aircraft shall be loaded in accordance with AR 95-16, "Weight and Balance: Army Aircraft". Nonmilitary aircraft shall be loaded to comply with Civil Air Regulations.

(g) Nonmilitary airfields used for loading and unloading explosives will be provided with aircraft firefighting service equal to Army standards.

(h) At nonmilitary airfields used by US Army Flight Activities, aircraft rescue and fire protection is normally provided by the host. If protection provided by the host does not meet the standards established in AR 420-90, Fire Prevention and Protection, and the DARCOM supplement to AR 420-90, Army fire department personnel and/or auxiliary firefighters will be used during periods of Army flight activities, including loading and unloading of explosives.

(i) In addition to protection provided by the host, protection will be furnished through use of portable fire extinguishers by operating agency personnel trained as auxiliary firefighters.

(j) As a minimum, four portable fire extinguishers should be available for firefighting purposes during all loading and unloading of explosives. Recommended extinguishers are: two each pressurized water type extinguishers, utilizing Aqueous Film-Forming Foam (AFFF) liquid concentrate, six percent, MIL-F-24385, and two each Potassium Bicarbonate Base Dry Chemical Extinguisher, 13.6 kilograms (30 lb) capacity.

(4) Damaged shipments. Air shipments of explosives or ammunition received at a DARCOM establishment in a damaged condition or not loaded in accordance with applicable requirements shall be reported on Discrepancy in Shipment Report (SF 361) in accordance with AR 55-38 "Reporting of Transportation Discrepancies in Shipments." If damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

(5) Containers. Containers of explosives in aircraft shall not be opened or repaired.

e. *Water Transportation*.

(1) Transportation of explosives, ammunition, and other hazardous materials by water in vessels engaged in commercial service is regulated by the United States Coast Guard. Shipments overseas shall be made in accordance with the regulations of the carrier, the United States Coast Guard, or Department of the Army. (See AR 55-228, Transportation by Water of Explosives and Hazardous Cargo and TM 55-607 [Navy NAVSEA OP 3221 Rev. 1]. Loading and Stowage of Military Ammunition and Explosives Aboard Breakbulk Merchant Ships). Where route of travel requires passage under bridges, prior authorization from the responsible agency shall be obtained.

(2) Damaged shipments or shipments not stowed in accordance with pertinent regulations when received at a DARCOM establishment shall be reported on Discrepancy in Shipment Report (SF 361) in accordance with AR 55-38. If damage was due to improper preservation, packaging, or packing, SF 364 (Report of Discrepancy) will be prepared in accordance with AR 735-11-2.

(3) Containers of explosives and ammunition shall not be opened or repaired onboard a vessel except as required for dumping at sea or servicing weapons.

(4) Vessels in which explosives or ammunition are received shall be inspected after unloading to see that they are clean and free from loose explosives or other flammable materials and that warning placards, etc., are removed. Explosives sweepings will be destroyed.

CHAPTER 15
DISPOSAL, DESTRUCTION, DECONTAMINATION, AND DEMILITARIZATION OF ENERGETIC MATERIALS

15-1. Introduction. Most energetic materials cannot be safely disposed of by dissolving in solution and eliminating as sewage because they are insoluble in water, are generally toxic, and are hazardous to the environment. Disposal must be by burning, detonation, or chemical decomposition. The instructions in this chapter are for destroying limited quantities of explosive, pyrotechnic, incendiary, and smoke materials normally encountered during daily operations in laboratories, manufacturing plants, and storage facilities. When larger quantities are destroyed or reclaimed, special instructions will be furnished by the US Army Armament, Munitions, and Chemical Command (AMCCOM)/US Army Materiel Development and Readiness Command (DARCOM). When destruction is authorized, the provisions of all current applicable Army directives must be observed.

15-2. Disposal. Methods for destruction are generally based on the quantity and nature of materials to be destroyed, the facilities available, and the topography of the land. Destruction of explosive materiel will be accomplished by burning or detonation. The only exception to this policy is made in the case of small quantities of explosives which can be destroyed by chemical means as specified in paragraph 15-4. Burying energetic materials in the ground or dumping in waste places, pits, wells, marshes, shallow streams, rivers, inland waterways, or deep sea is absolutely prohibited. Existing locations, if known, of buried explosives and other energetic materials shall be appropriately marked with permanent type signs and measures shall be taken to prohibit unauthorized personnel from entering the area. Existing records identifying the type and quantity of energetic materials buried shall be maintained and the burial area shall be noted on installation drawings. Explosives which are dangerously deteriorated or cannot be definitely identified shall be destroyed by an approved method. Destruction shall not be undertaken without prior approval unless the organization or installation commander decides that immediate destruction of deteriorating explosives is necessary for the protection of life and property. All deteriorated materials thus destroyed must be accounted for, since Army regulations pertaining to the disposal of excess and surplus property apply to the destruction of such unserviceable property. Prior approval for destruction of routine waste is not required. Compliance with applicable federal, state, and local environmental restrictions and permits is mandatory. Review of all SOPs for destruction of energetic materials by the Installation Environmental Coordinator is mandatory.

15-3. Destruction by Burning or Detonation.

a. *Destruction Sites.*

(1) Site selection, physical security, personnel training, emergency equipment, and procedures are governed by applicable federal, state, and local environmental regulations, particularly applicable hazardous waste regulations, and by the safety considerations which follow. Open burning and open detonation operations will be conducted in accordance with applicable air, hazardous waste, and other environmental permits. The site selected for the destruction of explosives and other energetic materials shall be located at the maximum practicable distance from all magazines, inhabited buildings, public traffic routes, and operating buildings but not less than 732 meters (2,400 feet) unless pits or similar aids are used to limit the range of fragments and debris. In all disposal and destruction activities, the quantity of explosives that may be destroyed safely at one time shall be determined carefully by starting with a limited quantity and then gradually increasing that quantity until the optimum amount consistent with safe and efficient operation is determined. When trials prove that fragments and debris are limited to lesser ranges, the appropriate inhabited building distances may be used. Sites must also be located in relation to the direction of prevailing winds so that sparks will not be blown toward explosives location. Where possible, natural barricades shall be utilized between the site and operating buildings or magazines. When destroying explosives by burning, the possibility that the mass may detonate must be recognized and appropriate protective barriers or distance separation should be used to protect personnel and property. Open air burning and detonation of explosives and pyrotechnics for demilitarization is prohibited between sunset and dawn.

(2) Dry grass, leaves, and other extraneous combustible material in amounts sufficient to spread fire shall be removed from a 200 foot radius from the point of destruction. The grounds should be of well packed earth and shall be free from large stones and deep cracks in which explosives might lodge. Explosive materials shall not be burned or detonated on concrete mats.

(3) Fire-fighting facilities shall be readily available to extinguish brush or grass fires and, if necessary, to wet down the ground between burnings and at the close of each day's operations.

(4) Ordinary combustible rubbish, explosives, and explosives contaminated material shall be destroyed at separate locations. Where limited space does not permit separate burning areas, part of the explosives destruction ground may be reserved for burning rubbish provided the two areas are not operated simultaneously, and the area where rubbish has been burned is wetted down and inspected before explosives burning is resumed. Combustible material should be burned in an incinerator complying with National Fire Protection Association Standard No. 82 or in a substantial, wire-mesh enclosure (not over three-fourths inch openings).

(5) The demolition area or burning ground shall be serviced with telephones or two-way radio communication. A change house serviced with electricity is desirable.

b. *Explosives Material Awaiting Destruction.*

Explosives material awaiting destruction shall be stored at not less than intraline distance, based on the largest quantity involved, from explosives being destroyed. The material shall be protected against accidental ignition or explosion from fragments, grass fires, burning embers, or detonating impulse originating in materials being destroyed.

c. *Personnel Protection*.

(1) Operational shields with overhead and frontal protection will be provided to protect personnel. Where circumstances warrant their use, complete personnel protection shall be provided. Such structures should preferably be located at the appropriate inhabited building distance for the quantity and type of materials being detonated but in no case will this distance be less than 300 feet. Employees must use such protection when explosive materials are destroyed by detonation or when explosive materials which may detonate are being burned. When Class 1.3 material is being destroyed by burning, personnel must remain at the greatest practicable distance from the burning site but in no case shall personnel be permitted closer than the applicable public traffic route distances.

(2) During disposal and destruction operations, the number of people in the area exposed to the hazard must be kept to a minimum. Warning signs or road blocks shall be posted to restrict the area and to ensure proper segregation of activities. At least two people are needed in disposal and destruction operations and operations shall be arranged so that not all of the personnel are exposed to an incident. Personnel engaged in burning explosives should be provided with flame resistant clothing.

d. *Supervision and Training.*

(1) The disposal area and its operations shall be under the direct control of an experienced, trained supervisor responsible for all activities within the area. The supervisor shall be present during all burning and demolition ground operations. During the supervisor's absence, a competent qualified person will be in charge. The alternate shall have sole custody of all ignition devices. Prior to actual burning or detonation of explosives, all personnel including the demolition ground supervisor will be evacuated to a safe distance or protective structure affording adequate protection but consistent with the need to monitor the total operation until it is complete.

(2) Personnel employed at the destruction area shall be thoroughly trained regarding the nature of the materials handled, the hazards involved, and the precautions necessary. The danger of using unapproved, improvised methods and other deviations must be thoroughly instilled in the minds of the employees. It is essential that thorough training and vigilant supervision be provided.

(3) In the absence of specific regulations covering any phase of the destruction of explosive material, complete information will be forwarded through command channels to the Commander, DARCOM, ATTN: DRCSF, requesting instructions and guidance.

e. *Containers for Waste Explosives*. Explosives destined for the burning ground shall be in original closed packages or in containers of fire-retardant materials which will not contribute to the existing hazard by readily producing sparks when contacting rocks, steel, or other containers. Bags or containers made from easily ignited material shall not be used. Containers shall have closures that will prevent spilling or leakage of contents when handled or if overturned. Closures shall be of a type that will not 'pinch or rub explosives during closing and opening. The closures and surfaces of containers openings shall be thoroughly cleaned of explosive contamination to minimize the hazard during closing or opening.

f. Servicing of Destruction Site.

(1) Trucks transporting explosive material to burning or demolition grounds shall meet the requirements of Chapter 14. No more than two persons shall ride in the cab.

(2) Upon arriving at a burning or demolition ground, trucks may distribute explosives containers or explosives items to be destroyed at sites where destruction is to take place. As soon as all items have been removed, trucks shall be withdrawn from the burning or demolition area to a safe location until destruction is completed. Containers of explosives shall not be opened until the truck has been withdrawn

(3) (3) 'Containers of energetic materials items to 1!(destroyed at the destruction site shall be spotted and opened at least 10 feet from each other and from explosives material previously laid for destruction to prevent rapid transmission of file in event of premature ignition.

(4) Empty containers shall be closed and moved a sufficient distance away to prevent charring or damage during burning of the explosives. Empty containers may be picked up by truck on the return trip after delivery of the next quantity to be destroyed.

(5) When materials being processed at destruction sites are to be handled by gasoline or diesel powered fork lift truck, the requirements of Chapter 12 will be observed. All such material handled will be properly packaged and must not be contaminated with explosives.

g. *General Burning Requirements*.

(1) Except in specific cases, energetic materials shall not be burned in containers.

(2) Bulk initiating explosives and others used predominantly in detonators and photoflash compositions shall be destroyed by detonation except that small quantities (not exceeding 28 grams) may be decomposed chemically.

(3) Loose explosives, other than initiating explosives, may be burned in beds not more than three inches deep. Wet explosives may require a thick bed of readily combustible material such as excelsior underneath and beyond to assure that all the explosives will be consumed once the materials are ignited. From the end of the layer of explosives the combustible material should be extended in a train to serve as the ignition point. When an ignition train of combustible material leading to the explosives is used, it must be arranged so that both it and the explosives burn in the direction from which the wind is blowing. The combustible train of the explosive, if ignited directly, must be ignited by a safety fuse of a length which will permit personnel to withdraw safely to the protective shelter, or by black powder squib initiated by an electric current controlled from a distance or structure which assures safety to personnel should the total quantity of explosives detonate. In some cases, it may be necessary to tie two or more squibs together to assure ignition of the combustible train. When a misfire occurs, personnel shall not return to the point of initiation for at least 30 minutes. Not more than two qualified persons shall be permitted to examine the misfire.

(a) Loose, dry explosives may be burned without being placed on combustible material if burning will be complete and the ground does not become unduly contaminated. The ground must be decontaminated as frequently as is necessary for the safety of personnel and operations. Qualified inspectors shall examine the sites after each burning to determine if these requirements are met. Volatile flammable liquids shall not be poured over explosives or the underlying combustible material to accelerate burning, either before or during the burning of materials.

(b) Wet explosives shall not be burned without first preparing a bed of nonexplosive combustible material upon which the explosives are placed to assure complete burning. It is usually necessary to burn RDX wet to prevent detonation.

(c) Pyrotechnic materials collected as described in paragraph 15-5h(3) may be burned, except as noted below, by emptying the containers or buckets containing the oil and pyrotechnic mixture into a shallow metal pan and igniting as described above. The opened containers may be burned with the explosives. Burning of colored smokes and WP and HC mixes requires specific authorization of the Commander, AMC, ATTN: AMCSF.

(4) Parallel beds of explosives prepared for burning shall be separated by not less than 45.7 meters (150 feet). In repeated burning operations, care must be taken to guard against material being ignited from smoldering residue or from heat retained in the ground. Burnings shall not be repeated on previously burned-over plots for 24 hours unless the burning area has been thoroughly soaked with water and an inspection of the plot by competent personnel has been made to assure the safety of personnel during a subsequent burning operation.

(5) Some types of explosives and tracer or igniter compositions give off toxic fumes when burned Proper protective respiratory equipment, such as hose masks, airline masks, and self-contained breathing apparatus shall be worn where such fumes are likely to be encountered.

h. *Materials for Detonating Explosives.*

(1) Detonation of explosives should, where practicable, be initiated by electric blasting caps using blasting machines or permanently installed electric circuits energized by storage batteries or conventional power line. Improvised methods for exploding electric blasting caps shall not be used. When items to be detonated are covered with earth, as specified in paragraph 15-3i(1), blasting caps shall not be buried beneath the ground level with the initiating charge. The initiating explosives should be primed with primacord of sufficient length to reach up through the covering to a point where the blasting cap may be connected above the ground level.

(2) Special requirements for using electric blasting caps and electric blasting circuits:

(a) Electric blasting caps, other electric initiators, electric blasting circuits and the like may be energized to dangerous levels by extraneous electricity such as: static electricity, galvanic action, induced electric currents, high tension wires. and radio frequency energy from radio, radar, and television transmitters. Safety precautions shall be taken to reduce the probability of a premature initiation of electric blasting caps and explosives charges.

(b) The shunt shall not be removed from the lead wires of the blasting cap until the moment of connecting them to the blasting circuit, except during electrical continuity testing of the blasting cap and lead wires. The individual who removed the shunt should ground himself or herself by grasping the firing wire prior to performing the operation in order to prevent accumulated static electricity from firing the blasting cap.

NOTE

After electrical continuity testing of the blasting cap, the lead wires must be short-circuited by twisting the bare ends of the wires together immediately after testing. The wires shall remain short circuited until time to connect them to the blasting circuit.

(c) When uncoiling the lead wires of blasting caps, the explosives end of the cap should not be held directly in the hand. The lead wires should be straightened out as far as necessary by hand and shall not be thrown, waved through the air, or snapped as a whip to unloosen the wire coils. Avoid loops by running lead wires parallel to each other and close together. If loops are unavoidable, keep them small. Keep wires on the ground in blasting layouts.

(d) Firing wires shall be twisted pairs. Blasting circuit firing wires shall at all times be twisted together and connected to ground at the power source and the ends of the circuit wires where blasting cap wires are connected except when actually firing the charge or testing circuit continuity. The connection between blasting caps and circuit firing wires must not be made unless the power end of the circuit lead (firing wires) are shorted and grounded. The following methods should be followed when connecting electric type blasting cap lead wires to the firing circuit wires:

1 Check wires leading to the blasting machine for continuity and stray currents.

2 Test electric blasting cap wires for electrical continuity, and after the test, connect to wires leading to the blasting machines.

3 Evacuate all but two, persons from the area. Place cap into charge to be detonated.

4 Unshort firing lead wire circuit and check for continuity.

5 Connect firing lead wire to blasting machine and fire charges.

6 After firing, remove lead wires from blasting machine and twist the end to short them.

(e) Electric blasting or demolition operations and unshielded electric blasting caps should be separated from radio frequency energy transmitters by the minimum distances specified in tables 15-1, 2, and 3. These distances apply to all parts of the operation, including the lead wires of the cap and the firing wires circuit. Before connecting electric blasting caps to the firing wires, the blasting circuit must be tested for the presence of extraneous electricity by the following test:

1 Arrange a dummy test circuit, essentially the same as the actual blasting circuit except that a No. 47 radio pilot lamp of known good quality inserted in place of the blasting cap shall be used without applying electric current to the circuit. Any glow is evidence of the presence of possible dangerous amounts of RF energy and blasting operations in such areas must be performed with non-electric blasting caps and safety fuse.

2 The Dupont Blaster's Multimeter, Model 101, may be substituted for the No. 47 radio pilot lamp. If the exposure is to radar, television, or other microwave transmitters, the actual blasting circuit, with blasting cap included, but without other explosives shall be used to test for extraneous electricity. Personnel performing such tests must be provided protection from the effects of an exploding blasting cap. Distances prescribed in tables 15-1, 2, and 3 should be used as a guide in the selection of sites for electric blasting operations in the vicinity of radar and other microwave transmitters.

Table 15-1. Minimum Safe Distances Between RF Transmitters and Electric Blasting Operations

Transmitter power (watts)	Minimum safe distance meters (feet)			
	Commercial AM broadcast transmitters		HF transmitters other than AM broadcast	
100	228.6	(750)	228.6	(750)
500	228.6	(750)	518.2	(1,700)
1,000	228.6	(750)	731.5	(2,400)
4,000	228.6	(750)	1,463.0	(4,800)
5,000	259.1	(850)	1,676.4	(5,500)
10,000	396.2	(1,300)	2,316.5	(7,600)
25,000	609.6	(2,000)	3,657.6	(12,000)
50,000[1]	853.4	(2,800)	5,181.6	(17,000)
100,000	1,188.7	(3,900)	7,315.2	(24,000)
500,000[2]	2,682.2	(8,800)	16,764.0	(55,000)

[1]Present maximum power of US broadcast transmitters in Commercial AM Broadcast Frequency Range (0.535 to 1.605 MHz).
[2]Present maximum for international broadcast.

Table 15-2. Minimum Safe Distances Between Mobile RF Transmitters and Electric Blasting Operations

Transmitter Power Watts	Minimum Safe Distances Meters (Feet)									
	MF 1.6 TO 3.4 MHZ Industrial		HF 28 TO 29.7 MHZ Amateur		VHF 35 to 36 MHZ Pub. Use42 to 44 MHZ Pub. Use50 to 54 MHZ Amateur Public Use		VHF 144 to 148 MHZ Amateur150.8 to 161.6 MHz Public use		UHF 450 to 460 MHZ	
5[1]										
10	12.2	(40)	30.5	(100)	12.2	(40)	4.6	(15)	3	10)
50	27.4	(90)	67	(220)	27.4	(90)	10.7	(35)	6.1	(20)
100	38.1	(125)	94.5	(310)	39.6	(130)	15.2	(50)	9.1	(30)
180[2]							19.8	(65)	12.2	(40)
250	61	(200)	149.4	(490)	62.5	(205)	22.9	(75)	13.7	(45)
500[3]					88.4	(290)				
600[4]	91.4	(300)	231.6	(760)	96	(315)	35	(115)	21.3	(70)
1,000[5]	122	(400)	298.7	(980)	125	(410)	45.7	(150)	27.4	(90)
10,000[6]	381	(1,250)			396.2	(1,300)				

[1]Citizens band radio (walkie-talkie) (26.96 to 27.23 MHz) - Minimum safe distance - five feet.
[2]Maximum power for 2-way mobile units in VHF (150.8 to 161.6 MHz range) and for 2-way mobile and fixed station units in UHF (450 to 460 MHz range).
[3]Maximum power for major VHF 2-way mobile and fixed station units in 35 to 44 MHz range.
[4]Maximum power for 2-way fixed station units in VHF (150.8 to 161.6 MHz range).
[5]Maximum power for amateur radio mobile units.
[6]Maximum power for some base stations in 42 to 44 MHz band and 1.6 to 1.8 MHz band.

Table 15-3. Minimum Safe Distances Between TV and FM Broadcasting Transmitters and Electric Blasting Operations

Effective radiative power (watts)	Minimum safe distances meters (feet)					
	Channels 2 to 6 and FM		Channels 7 to 13		UHF	
up to 1,000	304.8	(1,000)	228.6	(750)	182.9	(600)
10,000	548.6	(1,800)	396.2	(1,300)	182.9	(600)
100,000[1]	975.4	(3,200)	701	(2,300)	335.3	(1,100)
316,000[2]	1,310.6	(4,300)	914.4	(3,000)	442	(1,450)
1,000,000	1,767.8	(5,800)	1,219.2	(4,000)	610	(2,000)
5,000,000[3]	2,743.2	(9,000)	1,889.8	(6,200)	914.4	(3,000)
10,000,000	3,109	(10,200)	2,255.5	(7,400)	1,066.8	(3,500)
100,000,000	1,828.8					(6,000)

[1]Present maximum power, channels 2 to 6 and FM.
[2]Present maximum power, channels 7 to 13.
[3]Present maximum power, channels 14 to 83.

(f) Blasting or demolition operations shall not be conducted during an electrical storm or when a storm is approaching. All operations shall be suspended, cap wires and lead wires shall be short-circuited, and all personnel must be removed from the demolition area to a safe location when an electrical storm approaches.

(g) Prior to making connections to the blasting machine, the firing circuit shall be tested with a galvanometer for electrical continuity. The individual assigned to make the connections shall not complete the circuit at the blasting machine or at the panel, nor shall he/she give the signal for detonation until he/she is satisfied that all persons in the vicinity are in a safe place. When used, the blasting machine or its actuating device shall be in this individual's possession at all times. When the individual uses a panel, the switch must be locked in the open position until ready to fire and the single key or plug must be in his/her possession.

(h) Electric blasting caps must be in closed metal boxes when being transported by vehicles equipped with two-way radios and also when in areas where extraneous electricity is known to be present or is suspected of being present.

(3) Safety fuses may be used in the detonation of explosives where methods described in 15-3h(1) above cannot be accomplished. Safety fuse, when used, must be tested for burning rate at the beginning of each day's operation and whenever a new coil is used. Sufficient length of fuse shall be used to allow personnel to retire to a safe distance, but under no circumstances should a length be less than three feet or have less than 120 second burning time. Crimping of fuse to detonators must be accomplished with approved crimpers. Safety fuse which is too large in diameter to enter the blasting cap without forcing shall not be used. Before igniting the safety fuse, all personnel except the supervisor and not more than one assistant shall retire to the personnel shelter or be evacuated from the demolition area.

(4) When using blasting caps involving the electric or non-electric system of destruction, the explosives end of the blasting cap shall always be pointed away from the body.

i. Detonation of Explosives.

(1) Explosives to be destroyed by detonation should be detonated in a pit not less than four feet deep and covered with not less than two feet of earth. The components should be placed on their sides or in position to expose the largest area to the influence of the initiating explosives with an adequate number of demolition blocks placed in intimate contact on top of the item to be detonated and held in place by earth packed over the demolition blocks. Bulk explosives can be used as a substitute for demolition blocks. Where space permits and the demolition area is remotely located from inhabited buildings, boundaries, work areas, and storage areas, detonation of shells and explosives may be accomplished without the aid of a pit. In either event, however, the total quantity to be destroyed at one time, dependent on local conditions, should be established by trial methods to assure that adjacent and nearby structures and personnel are safe from the blast effect or missiles resulting from the explosion Rocket solid propellants should not be destroyed by detonation (paragraph 153Pt-.

(2) After each detonation, a search shall be made of the surrounding area for unexploded materials. Lumps of explosives may be picked up and prepared for the next detonation.

(3) In case of misfires, personnel shall not return to the point of detonation for at least 30 minutes after which not more than two qualified persons shall be permitted to examine misfire.

(4) AR 95-50 outlines the organization and functions of Regional Airspace Subcommittees and establishes uniform procedures for the handling of airspace problems. DARCOM installations will request, through channels, airspace clearance for demolition ground activities in accordance with these regulations.

j. Dynamite. Unopened boxes of exuding dynamite to be destroyed should be burned on a bed of combustible material without being opened. Precautions must be taken to protect personnel and property from possible detonation. Individual cartridges may be burned in a single layer not greater in width than the length of one cartridge, on a bed of combustible material. Dynamite awaiting destruction shall be shielded from the sun. Frozen dynamite is more likely to detonate during burning than normal cartridges. Destruction of dynamite by detonation may be accomplished where the location will permit this method of destruction. Care in priming to assure complete detonation of the quantity must be taken.

k. Initiating Explosives. When relatively large quantities of initiating explosives such as lead azide or mercury fulminate are to be destroyed, detonation is the best method. The bags containing the explosives should be kept wet while being transported to the demolition area. A predetermined number of bags should be removed from the containers, carried to the destruction pit, placed in intimate contact with each other and blasting caps used to initiate the explosives. The remaining explosives shall be kept behind a barricade with overhead protection during the destruction operations and located at a distance that will assure safety.

l. *RDX and PETN.* RDX and PETN may be burned as described in paragraph 15-3g. Since RDX and PETN are usually collected wet, they should be spread out and partially dried prior to burning. If the wet material will burn incompletely and with difficulty on the combustible bed, before any preparation for initiation is attempted fuel oil may be sprinkled over the bed of combustible material upon which the explosive is placed.

m. *Propelling Charges*. Propelling charges with igniters may be burned without slitting but in all cases igniter protector caps shall be removed from the charges to be burned. Protection must also be provided against possible projection of the charges and explosion. Propelling charges must not be piled one on the other but shall be burned in single layer of charges laid side by side. Core igniter type charges in the single layer should be separated by a distance equal to one caliber.

n. *Black Powder.*

(1) Black powder is best disposed of by dissolving out the potassium nitrate in a closed system and disposing of the solid wastes separately. It may also be burned as described below. Upon drying, wet black powder may retain some of its explosive properties since the nitrate may not have been removed completely.

(2) Only tools of wood or spark-resistant metal will be used in opening the containers. The contents of only one container will be burned at one time; no quantity should exceed 50 pounds. The powder must be removed from the container and spread on the ground in a train approximately two inches wide, so that no part of the train comes closer than 10 feet to another part. To ignite the powder bed, use a train of flammable material approximately 25 feet in length placed so that the train and the bed of powder burn into the direction from which the wind is blowing. Emptied black powder containers will be thoroughly washed with water. Serious explosions have occurred during handling of supposedly empty black powder cans. Safety precautions shall be observed.

o. *Pyrotechnic Materials*. Loose pyrotechnic materials should be burned under the same conditions as black powder. Water-wet pyrotechnic materials may be burned in small quantities in furnaces designed and approved for that purpose.

p. *Rocket Solid Propellants*.

(1) Wherever practicable, propellant must be removed from rocket motors and destroyed by burning. In the event removal of the propellant is not practicable, the rocket motor should be positioned or restricted to prevent movement and propellant in the units shall be destroyed by static firing. When units are to be destroyed by static firing, complete details of the procedures must be submitted to the Commander, DARCOM, ATTN: DRCSF for approval.

(2) Rocket or missile propellants (solid) may weigh as much as several thousand pounds per grain and the polymer-oxidizer type may be extremely difficult to ignite at atmospheric pressures. Large size rocket motors for specific systems may be destroyed in accordance with instructions contained in technical manuals or technical bulletins applicable to such systems.

15-4. Destruction by Chemical Means. The chemical destruction of loose explosives, except as provided below, shall not be permitted unless approval is given by the Commander, DARCOM. Chemical methods must be supervised by qualified personnel having knowledge of chemistry. Chemical methods shall not be used in an attempt to destroy explosives which are enclosed or pressed into components such as detonators. The following procedures may be used under adequate supervision for 28 grams or less of the explosives named.

a. *Mercury Fulminate*. Place a quantity of aqueous sodium thiosulfate (hypo) solution (20 percent by weight of sodium thiosulfate) equal to 10 times the weight of mercury fulminate to be destroyed in a wood or earthenware container. While agitating the hypo solution, add water-wet mercury fulminate. The mixture shall be agitated by air or mechanical means but not by hand. Agitation must be continued until all fulminate has been dissolved, usually within two hours. Operators shall keep to the windward of the container or wear gas masks to avoid inhaling any cynogen gas evolved.

b. Nitroglycerin. Small quantities of nitroglycerin may be neutralized or destroyed with a mixture of the following solutions: Solution A. Sodium sulfide (pulverized) (nine parts by weight) and water (30 parts by weight).

Solution B. Denatured ethyl alcohol (70 parts by weight) and acetone (20 parts by weight).

Do not combine the two solutions until immediately before use since potency of the mixed solutions diminishes on storage. This mixture should be used only for very small quantities of nitroglycerin (e.g., the oily film that adheres to surfaces after the nitroglycerin has been removed with sponges or absorbed in wood pulp or sawdust). Operators using this solution should wear rubber gloves.

c. Black Powder. Black powder may be completely destroyed by leaching or washing with large quantities of water and disposing of the washings separately from the residue.

d. Lead Azide.

(1) Lead azide accumulated on surfaces should be taken up with water wet cloths. The cloths should then be washed out in one of the solutions named below after which the complete desensitizing treatment is carried out in the solution. The cloths should be thoroughly washed with water before reuse. Empty shipping bags should be turned inside out and treated while still water-wet.

(2) The preferred chemical method for destroying lead azide is to use a 20 to 25 percent aqueous solution of ceric ammonium nitrate. When small quantities of lead azide are destroyed in this manner the reaction is not violent. Since one of the products of the reaction is a gas, the ending of the gas evolution indicates completion of destruction.

15-5. Decontamination.

a. *Decontamination Requirements.*

(1) The cleansing of equipment, buildings, and grounds of explosive materials is a difficult, tedious, and sometimes hazardous operation. Because of the wide variety of materials, the existence of cracks, crevices, and cavities, and the possibility of explosions and the evolution of toxic or explosive gases, the operations and techniques must be made as simple as possible and various precautions taken to ensure safety of personnel and completeness of decontamination. Serious accidents have occurred through the subsequent handling or heating of incompletely decontaminated equipment.

DARCOM Safety Manual and DARCOM Regulations 385-series provide detailed safety measures.

(2) Loading plants, because of the use of a number of explosive materials, present particularly difficult problems of decontamination. The procedures appropriate to several different explosives manufacturing plants may be required for the decontamination of different parts of an individual loading plant.

(3) With the growing complexity of modern military explosives and propellants because of the introduction of new nonexplosive ingredients as well as mixtures of explosives, the problem of decontamination is increased correspondingly. New and special compositions, therefore, should be given careful technical consideration before decontamination operations are undertaken.

(4) A necessary function of decontamination is the collection of industrial wastes for destruction or reclamation. Elaborate controls are required to assure that these collection efforts are performed safely and economically without causing down-time in essential operations.

b. Decontamination and Dismantling Explosives Establishments. The decontamination and dismantling procedures to be followed for explosives establishments upon cessation of activity or upon conversion to other uses shall be outlined in detail as prescribed in TB 700-4. Requirements shall be developed for cleaning and dismantling equipment preparatory to repair or maintenance. Any equipment used in an explosive operation which may subsequently be used in operations with non-explosive material or explosives other than that for which the equipment was used originally shall first be given whatever treatment is necessary to insure that no explosive material remains. Decontamination markings and the use of DA Form 3803, Materiel Inspection Tag, should be included as a part of these requirements.

c. Decontamination Operations.

(1) Wherever practicable, decontamination is affected by the physical operations of washing, steaming, and vacuuming. While washing operations suffice for most pyrotechnic materials, some smoke and incendiary compositions present explosion hazards when wet with water. A small amount of water contacting hexachloroethane (HC) smoke mixture may cause an explosion and release of toxic fumes. Metal objects such as nitrators, centrifuges, tanks, piping, etc. are washed with water and steamed. Wooden objects such as railings, paddles, etc. and buildings such as dry-houses, and packing materials, gaskets, etc., are destroyed by removing and burning after preliminary cleaning. Earth that is so contaminated as to offer a fire or explosion hazard is wetted, scraped up, and burned at a burning ground.

(2) Free acid present in equipment requires neutralization as well as washing and a five percent solution of sodium carbonate (soda ash) is used for this purpose. Because of the uncertainty of complete removal of explosives in all cases by the physical methods described, chemical methods are used also to supplement these. Standard decontamination procedures include the decontaminating chemical shown by table 15-4.

d. Collection of Contaminated Industrial Wastes. Industrial wastes which may contain explosive materials and chemical agents shall be collected only in holding, storage, or disposal facilities specifically designed and permitted (i.e., having environmental operating permits) for that purpose. Disposal into sanitary sewers, septic tanks, sanitary filter tanks, and unlined sumps, settling basins, or leaching pits is prohibited except as specifically authorized by permit. Sumps should be desensitized and cleaned at regular intervals. Cracks and crevices may contain explosives residue. Such residue must not be subjected to impact or friction from such sources as high pressure water streams, scraping tools or devices, etc., which may initiate the sensitive explosives. Quantities of initiating explosives in excess of 28 grams shall be destroyed by burning or detonation (see paragraph 15-3). Explosive materials to be removed from a settling basin should be maintained wet until removed. The more sensitive explosives should be maintained wet until destroyed. Materials containing powdered metals should be kept under water to prevent any dangerous rise in temperature which might otherwise be developed in the reaction between the metals and a small quantity of water.

Table 15-4. Decontaminating Chemicals

Contaminant	Decontaminating chemical
Lead azide	Ceric ammonium nitrate
Mercury fulminate	Sodium thiosulfate
Nitroglycerin	Methanolic sodium sulfite
Nitrocellulose	Sodium hydroxide
Smokeless powder	Sodium hydroxide and acetone
TNT	Sodium carbonate and sellite
Tetryl	Sodium carbonate and sellite or acetone
Pentolite	Acetone
White phosphorus	Copper sulphate solution

e. *Deposition from Waste Liquids.* When sumps or basins are properly designed, the wash water which passes beyond filters and basins should be free from significant amounts of explosive materials. If the effluent is discharged into a public stream, river, etc, it must not contain more explosives than permitted by local and state regulation. Consideration should be given to the possibility of deposition of explosive materials on the banks of streams or marshes during periods of drought, as well as to any possible subsequent precipitation of explosives with change of temperature, acidity, or concentration of the waste water. Where uncertainty exists regarding the composition of waste waters, competent technical advice and assistance should be obtained.

f. *Handling Water-Soluble Materials*. Where ammonium picrate, black powder, or other materials which are appreciably soluble in water are handled, the amount of dissolved material should be kept as low as practicable. Floors should be swept before washing down to reduce the quantity of dissolved material in the wash water.

g. *Destruction of Collected Solid Wastes*. Contaminated solid waste material should be taken in closed containers, as soon as practicable, to buildings set apart for its treatment or to the burning ground to be destroyed in an appropriate manner. Collected explosive and chemical wastes must not be disposed of by being buried or thrown in any streams or tidewater unless they are decomposed by water. Disposal of decomposed wastes in streams or tidewater will be allowed only if permitted by federal, state, and local laws and regulations.

h. *Collection of Explosives Dusts.*

(1) Dust collecting systems may be used to aid cleaning, to lessen explosion hazards, and to minimize industrial job-incurred poisoning and dermatitis.

(2) Examples of high explosives dusts which may be removed by a vacuum system are TNT, tetryl, ammonium picrate, composition B, and pentolite. A wet collector, which moistens the dust close to the point of origin and keeps it wet until the dust is removed for disposal, is preferred except for ammonium picrate which should be collected in a dry system.

(3) More sensitive explosives such as black powder, lead azide, mercury fulminate, tracer, igniter, incendiary compositions, and pyrotechnic materials may be collected by vacuum in this manner, provided they are kept wet with the wetting agent, close to the point of intake. The vacuum (aspirator) systems must be so arranged that the various types of explosives are collected separately or in a manner to avoid mixture of dissimilar hazards; i.e., black powder with lead azide. Provision should be made for the proper liberation of gases that may be formed. The use of vacuum systems for collecting these more sensitive materials should be confined to operations involving small quantities of explosives; for example, in operations involving fuzes, detonators, small arms ammunition, and black powder igniters. Potential fire and explosion hazards can be minimized by collecting scrap pyrotechnic, tracer, flare, and similar mixtures in No. 10 mineral oil. Satisfactory techniques include placing the oil in catch pans and scrap transporting containers at the various operations throughout the plant, and by having individual oil containers serve as collection points for multiple operations. In the latter case, nominal quantities of dry scrap may accumulate at operating locations before they are delivered to collection points and placed in containers of oil. The level of oil should be kept at least 2.54 centimeters (one inch) above the level of any pyrotechnic mixture in the containers. Containers in which scrap explosives and pyrotechnic materials have been collected should be removed from the operating buildings for burning at least once per shift. Where oil is used, fire-fighting equipment satisfactory for Class B fires should be available. Carbon dioxide or foam extinguishers are recommended.

i. *Location of Collection Chambers.*

(1) Wherever practicable, dry type explosives dust collection chambers, except portable units as specifically provided for in paragraph 15-5j(3), should be located outside operating buildings in the open or in buildings exclusively set aside for the purpose. In order to protect operating personnel from an incident involving the collection chamber, a protective barrier must be provided between the operating building and the outside location or separate building where the collection chamber is placed. If the collection chamber contains 11.35 kilograms (25 pounds) of explosives or less, the protective barrier may be a 30.5 centimeters (12 inch) reinforced concrete wall located at least 2.44 meters (eight feet) away from the operating building. The collection chamber must be separated from cubicle walls by at least three feet. If the collection chamber contains more than 11.35 kilograms (25 pounds) of explosives and is separated from the operating building by a 30.5 centimeters (12 inch) reinforced concrete wall, the wall must be separated from the operating building by a minimum of unbarricaded intraline distance. The cubicle may be placed at a minimum of barricaded intraline distance from the operating building if the protective barrier meets the requirements of DARCOM safety regulations for operational shields (including the required three foot distance between the barrier and the explosives) and for the quantity of explosive in the collection chamber, or if the barrier complies with the requirements of paragraph 12-11v for barricades. Barricaded and unbarricaded intraline distances will be based on the quantity of explosives in the collection chamber.

(2) When it is not practicable to locate dry type collection chambers outside the operating building, a separate room within the building may be set aside for the purpose. This room shall not contain other operations nor shall it be used as a communicating corridor or passageway between other operating locations within the building when explosives are being collected. Walls separating the room from other portions of the operating buildings must meet the requirements specified in DARCOM safety regulations for the quantity of explosives in the collecting chamber. If more than one collection chamber is to be located in the room, the room must be subdivided into cubicles by walls meeting the requirements of DARCOM safety regulations and not more than one collection chamber shall be in a single cubicle.

(3) Stationary and portable wet type collectors may be placed in the explosives operating bays or cubicles provided the quantity of explosives in the collectors does not exceed five pounds. If placed in separate cubicles, the explosives limits for the collectors may be increased to the amount reflecting the capabilities of the cubicle walls as operational shields. For greater quantities, the location requirements set forth above are applicable.

j. *Design and Operation of Collection Systems*.

(1) Collection systems and chambers shall be designed to prevent pinching explosives (especially dust or thin layers) between metal parts. Pipes or tubes through which dusts are conveyed should have flanged, welded, or rubber connections. Threaded connections are prohibited. The system shall be designed to minimize accumulation of explosives dusts in parts other than the collection chamber. Accordingly, pipes or ducts through which high explosives are conveyed shall have long radius bends with a centerline radius at least four times the diameter of ducts or pipes. Short radius bends may be used in systems for propellant powder provided they are stainless steel with polished interiors. The number of points of application of vacuum should be kept to a minimum. So far as practicable, each room requiring vacuum collection chambers, but not more than two bays, shall be serviced by a common header to the primary collection chamber. Wet primary collectors are preferred. Not more than two primary collectors (wet or dry type) should be connected to a single secondary collector. If an operation does not create a dust concentration which may produce a severe health hazard, manual operation of the suction hose to remove explosives dusts is preferred to a permanent attachment to the explosive dust producing machine. A permanent attachment increases the likelihood of propagation through a collection system of a detonation occurring at the machine. Interconnection of manually operated hose connections to explosives dust-producing machines should be avoided.

(2) Two collection chambers should be installed in series ahead of the pump or exhauster to prevent explosives dust from entering the vacuum producer in dry vacuum collection systems.

(3) Dry type portable vacuum collectors shall not be located in a bay or cubicle where explosives are present or in inclosed ramps but may be positioned outside the building or in a separate cubicle having substantial dividing walls for quantities of explosives not exceeding five pounds. Wet type portable vacuum collectors may be placed in explosives operating bays or cubicles provided the quantity of explosives in the collector is limited in accordance with the requirements of paragraph 15-5i. For dry collection of quantities in excess of 2.3 kilograms (five pounds) or wet collection of quantities in excess of 6.8 kilograms (15 pounds), the further provisions of paragraph 15-5i shall apply.

(4) The design of wet collectors shall provide for proper immersion of explosives, breaking up air bubbles to release airborne particles, and removal of moisture from the air before it leaves the collector to prevent moistened particles of explosives from entering the small piping between the collector and the exhauster or pump.

(5) At least once every shift, explosives dust shall be removed from the collector chamber to eliminate unnecessary and hazardous concentrations of explosives. The entire system should be cleaned weekly, dismantling the parts if necessary.

(6) The entire explosives dust collecting system shall be electrically bonded and grounded. The grounds must be tested frequently.

(7) Slide valves for vacuum collection systems are permitted. There shall be no metal-to-metal contacts with the metal slide. An aluminum slide operating between two ebonite spacer bars will not constitute a hazard.

15-6. Demilitarization.

a. Pollution Abatement and Waste Recycling Requirements. The problem of what to do with outdated ammunition to prevent both pollution and hazardous situations from occurring is an enormous one which dates back more than a century. At first glance, two answers become apparent, i.e., complete disposal or partial disposal with some recycling. The various chemical constituents of the warhead, propellant, or pyrotechnic are not only explosively hazardous but are frequently of a toxic character. Disposal by dumping into the world's oceans, incineration, or detonation have been shown to be not only dangerous but an addition to world pollution and as such, a persistent universal health hazard. Further, the problem of pollution from all sources (military and non military) became so acute in the United States in the early 1970's that both Presidential Executive Orders and Congressional legislation required that federal and private facilities be set up or converted to handle both pollution abatement and waste recycling. To this end, all US Military services (plus the AEC, now NRC) launched or vigorously continued their efforts to develop safe, efficient, and non-polluting methods of disposal or recycling of outdated ammunition, in particular, their energetic material content.

b. Recovery and Reclamation of Energetic Materials. Certain energetic materials such as relatively stable high explosives and pyrotechnics can be easily reclaimed and reloaded, but solid propellants which may have a limited storage life, require significant degrees of processing before they can be recycled or converted to other products. In many instances energetic material component recovery was not economically feasible. Energy conservation requirements strongly favor the recycling of energetic materials over pollution-free disposal (or the wasting) of these materials.

c. *Redesign of Ammunition for Use of Recycled Energetic Materials*. To have a safe, effective, and efficient program of ammunition recycling, ammunition that can be readily recycled must be available. To this end a new concept in ammunition design has been evolved. Ammunition items (inclusive of explosives, propellants, and/or pyrotechnics) will be designed and fabricated in such a manner as to be easily and safely recycled.

d. *Explosives Reclamation*. Preliminary removal of the high explosive charge from a mine, projectile, or shell usually involves the use of hot water or steam to liquefy the explosive which is then separated from the water by gravity, or contour drilling followed by high pressure water erosion to remove the high explosive residue. The new concept of ammunition which can be readily recycled by design, however has resulted in the prepackaging or encapsulation of the entire high explosive charge for easy and safe removal. After separation of the casing from the charge, table 15-5 summarizes the various procedures which have been developed to recover the individual constituents of the charge.

Table 15-5. High Explosive Reclamation

Constituent-composition	*Explosive recovery technique*
HBX from H-6 composition	A hot water erosion process removes the HBX from the warhead. Then the water explosive mixture flows into a vacuum kettle where the water is removed. The dried explosive is then dispensed through a multiported dispenser to an endless steel belt where it solidifies and is broken into flakes as it flows off the belt. Remelting and composition adjustment to form new HBX types or H-6 is then easily performed.
HMX from PBX 9404 composition	Preferential extraction of the binder is performed with concentrated (70 percent) technical grade nitric acid by adding the acid to the PBX component and heating the mixture to between 700C and 95°C for several minutes. After cooling to room temperature, the excess acid is withdrawn. The extraction procedure is repeated until the HMX is free of the binder. The acid is then diluted with water and the HMX collected by vacuum filtration. Yield is 82.0 to 86.6 percent.

Table 15-5. High Explosive Reclamation (Cont)

Constituent-composition	Explosive recovery technique
HMX from PBX compositions developed after 1974	The binders which are incorporated in these post-1974 compositions are selected for their heat sensitivity. For example, polypropylene-glycol-urethane can be degraded when heated to 160°C for 10 hours. The HMX can then be extracted with methylene chloride.
RDX from RDX composition A and RDX and TNT RDX composition B	Selective batch extraction of the wax in composition A using benzene in a soxhlet apparatus leaves the RDX. The TNT in composition B is extracted either batchwise or continuously in from soxhlet apparatus with benzene subsequent to extraction of the wax with heptane. This procedure leaves the RDX intact.
RDX plus 0.03 percent desensitizer from composition A-3	The wax is removed (leaving the RDX) by selective solution using a batch process in which a benzene-water azeotrope is continuously circulated through an agitated composition A-3/benzene slurry.
RDX from composition B	Selective solution of TNT and desensitizer with benzene in a closed system.
RDX from composition C-3	Selective solution of all but the RDX content of the composition is accomplished by agitation of a slurry of composition C-3 and methanol (or acetone) in a kettle.
Tetryl from tetryl-metal stearate mixture	Tetryl is selectively dissolved by continuous acetone extraction followed by water precipitation to recover the tetryl.
Tetryl from tetryl-stearic acid mixture	Separation is accomplished by reaction of the mixture with a dilute solution of the sodium bicarbonate or carbonate at 900C, cooling to room temperature, and then washing the tetryl with cold water. The tetryl is then recrystallized from acetone-water. Large pellets of the tetryl-stearic acid mixture require pre-treatment with an acetone soak.
TNT from amatol	The TNT is extracted with boiling water through a stainless steel mesh thus removing dirt and metal impurities. After the molten TNT settles, it is drawn off and rewashed with boiling water under agitation four times in a similar fashion. The TNT is then precipitated in cold water or run directly into graining kettles for immediate reuse.
TNT from 10/90 and 50/50 pentolite	TNT is selectively dissolved with benzene at 700C followed by cooling, filtering, and evaporation of the benzene to obtain the TNT.
TNT and tetryl from tetrytol 75/25	TNT is selectively dissolved using a xylene-heptane (50/50) mixture. This procedure recovers 90 percent of the tetryl.
TNT from warheads	TNT is selectively dissolved using xylene.

e. Propellants Reclamation. Solid ammunition propellants are difficult to recycle because the smokeless base(s) (nitrocellulose and/or nitroguanidine) used in the ammunition will deteriorate with age. Solid rocket propellants in many instances can be recovered as shown in table 15-6. However, the polymeric binder used in solid rocket propellants is a cross-linked material which is insoluble in solvents making it impossible to remove the binder simply by solvent extraction. Furthermore, the finely divided metal and oxidizer particles are intimately coated with the binder which is also impervious to water making it impossible to remove a water-soluble oxidizer from the metal and binder. This impediment in recycling calls for chemical cleavage of the binder linkage or the use of binder molecular structures which can be thermally degraded. Liquid propellants, on the other hand, do not present much of a recycling problem. They usually consist of a fuel and an oxidizer which are both usually basic industrial chemicals that can be stored separately for an indefinite period of time. Hence, liquid propellants are always essentially recovered before actual use.

Table 15-6. Propellant Reclamation

Constituent-ammunition item or composition	*Propellant constituent recovery technique*
Ammonium perchlorate (or other oxidizer) and fuel from binder	The oxidizer is usually water-soluble. The oxidizer extraction process is efficiently performed with the cooling water used to cool the propellant grains during the shredding process. The oxidizer is then recrystallized and reused. The inert binder and metal fuel are further separated for the purpose of recovering the metal either before or after incineration.
Contaminants from .50 cal ammunition	The removal of contaminating igniter and tracer compositions from .50 cal propellant is performed by selective solution using a water spray from a fish-tail type of sprayer which emits the water at a 90 degree angle to the surface of the propellant powder as it is vibrated on a Day Roball Gyrator screen.
Nitrocellulose from deteriorated propellants	Recovery of nitrocellulose is performed by solution or dispersion underwater, then careful molding to give a colloidal composition of nitrocellulose.
Nitrocellulose from single-base cannon powder containing DNT and dibutylphthalate (DBP)	Preferential solution of the DNT and DBP uses an extraction process with a mixture of benzene water.
Nitroglycerin propellants	A process of selective adsorption is used; i.e., a benzene solution of the various constituents of the composition are selectively adsorbed on materials such as Fullers earth, silicic acid, activated carbon, activated silicates, etc., followed by a desorption process.
Reclamation of cured polysulfide-perchlorate propellants	The waste cured propellant is reduced to a small particle size by passing it through a laboratory mill. It is then added to the extent of 20 percent of the total mixture to a normal mixture of propellant. The waste propellant re-liquefies to its precured state in the mixer by means of a molecular weight redistribution between the low molecular weight liquid polymer and the high molecular weight solid polymer. The reaction is complete in about 10 minutes.

f. Pyrotechnics Reclamation. As can be seen from the data in table 15-7, little work has been done on recycling the majority of pyrotechnic basic materials with the exception of the magnesium and sodium nitrate in illuminating flares and dyes in smoke components. Current investigations consist of attempts to recover the pyrotechnic materials from signal flares. However, the work to date can be considered as a pilot activity which can be further developed and applied to other pyrotechnic items and components.

Table 15-7. Pyrotechnic Reclamation

Constituent-composition	Pyrotechnic constituent recovery technique
Dyes from smoke compositions	Preferential solution with water leaves the dye plus other water insolubles for storage and later reuse in new units. The dyes can be further separated by extraction with a dilute aqueous mineral acid such as hydrochloric acid. If water is present in the dye, it can be extracted with alkaline solutions.
Magnesium from flare compositions	Water is used to selectively dissolve sodium nitrate and most of the binder material. The residual magnesium is then dried and sieved. In some instances the binder requires acetone or similar solvents.

APPENDIX A
CHARACTERISTICS AND DATA

TABLE A-1. Sensitivity Test Values of Explosives

Material	Impact test with 2 kilogram weight		Pendulum friction test, percent explosions	Rifle bullet test, percent explosions	Explosion temperature test, °C	Minimum detonating charge, gram of-		Electrostatic, sensitivity, joules
	PA APP (% TNT)	BM APP (%TNT)				lead azide	mercury fulminate	
Primary explosives								
Lead azide (pure)	29		100	-	-	-		0.01
DLA	29 to 43	13 to 28	-		340			
SLA	14	30	-		350			
CLA	14 to 21	-	-	-	-	-		
PVA-LA	29 to 35	13 to 16	-		344			
RD-1333	36	15	-		340			
DCLA	21 to 42	-	-		345			
Mercury fulminate	14	5	100		210	-	-	0.025
Diazodinitrophenol	14	5	100		195	-	-	0.25
Lead styphnate (normal)	21	8	-		282	-	-	0.0009
Tetracene	14	7			160	-	-	0.01
Aliphatic nitrate esters								
BTN	7	16	-	-	230	-	-	-
DEGN	-	-	-	-	237	-	-	-
Nitrocellulose								
Pyrocellulose (12.750/o N)	21	8	-	100	170	-	-	-
Blended	21	8	-	100	200			
Guncotton (13.3% N)	21	9	-	100	230	0.10		
Nitroglycerin	7	16	100	100	222			
Nitrostarch	36	-	-	-	217			
PETN	43	17	5	100	215	0.03	0.17	0.036
TEGN	307	100 +	0	-	225			
TMETN	-	-	100	-	235	-	-	-
Nitramines								
HMX	-	32 shoe) 0 (fiber shoe)	100 (steel	-	327	0.30	-	-
RDX	57	33	20	100	260	0.05	0.19	-
EDDN	64	75	-	-	445	-	2.0	
Haleite	-	48	0	-	190	0.21	0.13	
Nitroguanidine	-	47	0	0	275	0.20	-	-
Tetryl	57	26	0	70	257	0.10	0.19	-

TABLE A-1. Sensitivity Test Values of Explosives (Cont)

Material	Impact test with 2 kilogram weight		Pendulum friction test, percent explosions	Rifle bullet test, percent explosions	Explosion temperature test, °C	Minimum detonating charge, gram of-		Electrostatic, sensitivity, joules
	PA APP (% TNT)	BM APP (%TNT)				lead azide	mercury fulminate	
Nitroaromatics								
Ammonium picrate	121	100+	0	30	318		0.85	-
DATB	200	-	-	-	-	-	-	-
HNS	50	-	-	-	-	-	-	-
TATB	79	-	-	-	520	0.30	-	-
TNT -	-	-	0	0	475	0.26	0.24	0.06
Ammonium nitrate	221	100 +	0	0	no explosion	-	-	-
Binary								
Amatol	93 to 100	-	0	0	254 to 300	-	-	-
Composition A3	125	-	0	0	250 to 280	0.25	0.22	-
Composition B	100	75	-	20	278	0.20	0.22	-
Composition C3	100	100 +	0	40	280	-	-	-
Composition C4	> 100	-	0	20	263 to 290	0.20	-	-
55/45 Ednatol	-	95	0	0	190	0.22	0.22	-
75/25 Octol	170	0	-		350	0.30	-	-
70/30 Octol	136	-	0	-	335	0.30	-	-
50/50 Pentolite	86	34	0	80	220	0.13	0.19	
Picratol	100	100 +	0	0	285	-	-	-
70/30 Tetrytol	78	28	0	-	320	0.22	0.23	
Tritonal	71	73	0	60	470	0.30	-	-
Ternary								
Amatex 20	107 to 129	-	-	6	240	-	-	-
HBX-1	75	-	-	75	-	-	-	-
HBX-2	80	-	-	80	-	-	-	-
HTA-3	121	-	0	90	370	-	-	-
Minol-2	93	35	-	-	224 to 260	-	-	-
Torpex	50	75	-	100	260	-	0.18	-
Quanternary								
DBX	71	-		49	200	0.20	-	-

Table A-2. Effects of Explosives

Material	Brisance measured by-		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Trauzl lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Primary explosives										
Lead azide (pure)	40	-	-	-	4.68	5,400	-	40	-	-
DLA	38									
Mercury fulminate	27.3 to 59	-	-	-	4.17	5,400	-	37 to 50	-	-
Diazodinitrophenol	94 to 105	-	-	-	1.63	7,100	-	110	-	-
Lead styphnate (normal)	22 to 53	-	-	-	2.9	5,200	-	42		
Tetracene	40 to 70	-	-	-	-	-		51 to 63	-	-
Potassium dinitro-benzofuroxane	93	-	-	-	-	-	-	-	-	-
Aliphatic nitrate esters										
BTN	103	-	-	-	-	-	-	-	-	
DEGN	100	-	-		1.38	6,760	127	144 to 150	-	-
Nitrocellulose										
Pyrocellulose (12.75% N)	94									
Blended (13.30/o N)	99									
Guncotton	102	-	-	84	1.3	7,300	125	136 to 147	-	-
High nitrogen	108-120									
Nitroglycerin	120	-	-	-	1.6	7,700	140	185		
Nitrostarch(13.4% N)	-	-		83	0.90	6,190	145			
PETN	129 to 141	127	-	-	1.773	8,300	145	170	-	
TEGN	30.6	-	-	-	1.33	2,000	-	-		
TMETN	91	-	-	-	-	-		140	-	-
Nitramines										
HMX	125	-	-	1.89	1.89	9,110	170	159 to 165	-	-
RDX	125 to 145	135 to 141	141	-	1.770	8,700	150	170	-	-
EDDN	96	100	-	-	1.50	6,915	120	125	-	-

Table A-2. Effects of Explosives (Cont.)

Material	Brisance measured by-		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Trauzl lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Haleite	109 to 119	113 to 122	117 to 147		1.55	7,883	136	122 to 143	-	-
Nitroguanidine	73.5 to 84	95			1.70	8,100	104	78 to 101	-	-
Tetryl	113 to 123	115	121	117 to 125	1.71	7,850	145	125 to 145	-	-
Nitroaromatics										
Ammonium picrate	78 to 82.5	91 99			1.63	7,154	98	-	-	--
DATB	120	-	-		1.79	7,585				
HNAB	- -				1.77	7,250	-		123	--
HNS	120	-	-		1.70	7,000	-	-	-	--
TATB	90 -	-	-		1.937	8,000	-	-	-	--
TNT	- -	-			1.636	6,826	-	-	-	--
Ammonium nitrate	- -				1.0	2,800	-		75	
Binary										
Amatol	74 to 94 -		81	-	1.6	5,300 to 6,550	122	116 to 126	97	87
Composition A3	107 to 115	126	150	-	1.6	8,200	132	144	-	
Composition B	113	129 to 132	142	-	1.68	7,840	133	131	110	110
Composition C3	112	114 to 118	133	-	1.6	7,625	126	117	105	109
Composition C4	116	115 to 130	-	-	1.59	8,040	130	-		
CH6	128 -	-	-	-	8,223					
55/45 Ednatol	112	112	118		1.63	7,340	119	119	108	110
75/25 Octol	- -	-			1.81	8,364 to 8,643	-			
70/30 Octol	- -	-			1.80	8,310 to 8,377	-	-	-	-
50/50 Pentolite	114	126	131	113	1.62	7,402	126	121	105	107
Picratol	94	100	102	-	1.67	6,970	100	-	100	100
70/30 Tetrytol	111	118	119		1.61	7,350	-	120		
80/20 Tritonal	114	93	91		1.76	6,770	124	153	113	118

Table A-2. Effects of explosives (Cont)

Material	Brisance measured by-		Fragmentation of shell percent TNT	Copper cylinder compression test	Rate of detonation		Ballistic pendulum test percent TNT	Tares lead block test percent TNT	Relative blast effect, percent TNT	
	Sand test (% TNT)	Plate dent test percent TNT			At density	Meters per second			Pressure	Impulse
Ternary										
Amatex 20	-	-			1.61	6,944				
HBX-1	102		129		1.75	7,222	-		121	116
HBX-3	93.5	-	68	-	1.86	6,920	-		121	125
HTA-3	128	-	-	-	-	7,866	-			
Minol-2	86	66	-	-	1.77	6,200	143	165		
Torpex	122	120	126	-	1.8	7,660	134	161	122	125
Quanternary										
DBX	112	-	-	-	1.76	6,800				

Table A-3. Thermochemical Characteristics of Explosives

Material	Heat of combustion, calories per gram at constant	Heat of formation kilogram calories per mole	Products of explosion	
			Heat, calories per gram (H_2O gas)	Gas, milliliters per gram
Primary explosives				
Lead azide	-	-112 to -126.3	367	308
Mercury fulminate	938	-221 to-226	427	315
Diazodinitrophenol	-	956	820	-
Lead styphnate	1,251	92.3	460	440
Tetracene	-	270	658	1,190
Aliphatic nitrate esters				
BTN	2,167	368	1,458	-
DEGN	2,792	-99.4	1,161	-
Nitrocellulose				
Pyroxlyn (12% N)	-	-216	1,020	-
Guncotton (13.350/o N)	2,313	-200	1,020	883.2
High nitrogen (14.14% N)	- -191	1,810		
Nitroglycerin	1,603	-90.8	1,486	715
PETN	1,957	-128.7	1,510	790
TEGN	3,428	-603.7	750	-
TMETN	2,642	-422		
Nitramines				
HMX	2,231 to 2,253	11.3 to 17.93	1,480	
RDX	2,259 to 2,284	14.71	1,480	908
EDDN	2,013	156.1	128 to 159	
Haleite	2,477	20.11	1,276	908
Nitroguanidine	2,021	20.29	880	1,077
Tetryl	2,914	4.67 to 7.6	1,450	760
Nitroaromatics				
`Ammonium picrate	2,745	95.82	800	-
`DATB	-	-97.1 to-119	910	-
`HNAB	-	-58 to-67.9	1,420	-
`HNS 3,451		-13.9 to 1.87	1,360	-
`TATB	2,850	-33.46 to-36.85	1,018	-
`TNT	3,563 to 3,598	-10 to- 19.99	1,290	730
`Ammonium nitrate	-	88.6	381	980

Table A-4. Stability Test Values of Explosives

Material	75°C international test, percent loss in weight	100°C Heat Test, percent loss in weight in-		Vacuum stability test						
		1st 48 hr	2nd 48 hr	Sample, gm	100°C		120°C		150°C	
					ML	HR	ML	HR	ML	HR
Primary explosives										
Lead azide										
DLA		0.34	0.39	1	0.32	40	0.46	40	-	-
SLA		0.08	0.16	-	-	-	-	-	-	-
PVA-LA-	-	0.13	-	1	0.20	40	0.44	40	-	-
RD1333-	-	0.30	0.30	1	-	-	0.43	40	-	-
Mercury fulminate	0.18	----------	----------	----------	explodes	----------	----------	----------	-----	
Diazodinitrophenol	0.24	2.10	2.20	5	7.6	40				
Lead styphnate (normal)	-	1.5	1.5	1	0.4	40	0.4	40		
Tetracene	0.5	23.2	3.4							
Potassium dinitrobenzofuroxane	0.03	0.05								
Lead mononitroresorcinate	-	-	-	2.3	-	-	0.4	40	-	-
Aliphatic nitrate esters										
Nitrocellulose (12%N)	-	0.3	0	1	-	-	5.0	48	-	-
Nitroglycerin	3.5	3.5	1	11 +	16					
PETN	0.02	0.1	0.0	5	0.5	40	11 +	40	-	-
TEGN	-	1.8	1.6	1	-0.45	40	0.8 to 0.99	8		
TMETN	-	2.5	1.8	-	-	-	-	-	-	-
Nitramines										
HMX	-	0.05	0.03	5	0.37	40	0.45	40	0.62	40
RDX	0.03	0.04	0	5	-	-	0.9	40	2.5	40
Haleite	0.01	0.2	0.3	5	0.5	48	1.5 to 2.4	48	11 +	
Nitroguanidine	0.04	0.48	0.09	5	0.4	40	0.5	40	-	-
Tetryl	0.01	0.1	0.0	5	0.3	40	1.0	40	11 +	12
Nitroaromatics										
Ammonium picrate	0.12	0.1	0.1	5	0.2	40	0.4	40	0.4	40
DATB	-	-	-	1	-	-	0.03	48		
HNS	-	>1	-	-	-	-	-	-	-	-
TATB	-	17	-	-	-	-	-	-	-	-
TNT	0.04	0.1	0.1	5	0.1	40	0.4	40	0.7	40
Ammonium nitrate	0.0	0.1	0.0	5	0.3	40	0.3	40	0.3	40

Table A-4. Stability Test Values of Explosives

Material	75°C international test, percent loss in weight	100°C Heat Test, percent loss in weight in-		Vacuum stability test						
		1st 48 hr	2nd 48 hr	Sample, gm	100°C		120°C		150°C	
					ML	HR	ML	HR	ML	HR
Binary										
50/50 Amatol	-	-	5		0.3	40	1.0	40		
Composition B	-	0.2	0.2	5	0.7	48	0.9	48	11 +	48
Composition C3	-	-	-		1.21	48	11 +	48		
Composition C4	-	0.13	0.0	-	0.20	40				
55/45 Ednatol	-	0.2	0.1	5	0.7	40	11 +	24	-	-
75/25 Octol	-	-	5	-	-		0.39 to 0.65	40	11	40
70/30 Octol to 0.76	-	-	-	5	-	-	0.37	40	5.10	40
50/50 Pentolite	-	0.0	0.2	5	2.5	40	11 +	16	-	
Picratol	0.0	0.0	0.05	5	0.4	40	0.7	40	0.7	40
70/30 Tetrytol	-	0.1	0.1	5	3.0	40	11 +	40		
80/20 Tritonal	-	-		5	0.1	40	0.2	40	0.8	40
Ternary										
HBX-1	-	0.058	0.0							
HBX-2	-	0.70	0.0							
Minol-2	-			5	0.0	48	2.1	40	-	-
Torpex	-	0.0	0.10	5	0.2	40	1.5	40	11 +	16

Table A-5. Density Values of Explosives in Grams Per Milliliter

Material	Crystal or liquid	Pressure in kilopascals (pounds per square inch)							Cast
		20,685 (3,00)	34,475 (5,000)	68,450 (10,000)	103,425 (15,000)	137,900 (20,000)	206,850 (30,000)	275,800 (40,000)	
Primary explosives									
Lead azide (pure)	4.87								
DLA	-	-	-	-	3.14	-	-	-	-
SLA	-	-	-	-	3.31	-	-	-	-
PVA-LA	-	-	-	-	3.81	-	-	-	-
Mercury fulminate	4.43	3.0	3.2	3.6	3.82	4.0	4.1	-	-
Diazodinitrophenol	1.63 to 1.65	1.14							
Lead styphnate (normal)	3.02								
Tetracene	1.7	1.05							
Aliphatic nitrate esters									
BTN		1.520	-	-	-	-	-	-	-
-									
DEGN	1.39	-	-	-	--	-	-	-	-
Nitroglycerin	1.596	-	-	-	-	-	-	-	-

Table A-5. Density Values of Explosives in Grams Per Milliliter (Cont)

Material	Crystal or liquid	Pressure in kilopascals (pounds per square inch)							Cast
		20,685 (3,00)	34,475 (5,000)	68,450 (10,000)	103,425 (15,000)	137,900 (20,000)	206,850 (30,000)	275,800 (40,000)	
PETN	1.778	1.37	1.575	1.638	-	1.71	1.725	1.74	-
TEGN	1.335	-	-	-	-	-	-	-	-
TMETN	1.47	-	-	-	-	-	-	-	-
Nitramines									
HMX	1.905	-	-	-	-	-	-	-	-
RDX	1.816	1.46	1.52	1.60	1.65	1.68	1.70	1.71	
Haleite	1.66 to 1.77	-	1.28	1.38	1.44	1.49	-	-	-
Nitroguanidine	1.71	0.95	-						
Tetryl	1.73	1.40	1.47	1.57	1.63	1.67	1.71	1.71	1.62
Nitroaromatics									
Ammonium picrate	1.717	1.33	1.41	1.47	1.51	1.53	1.56	1.57	
HNAB	1.79	-	-	-	-	-	-	-	-
TNT 1.654	1.34	1.40	1.47	1.52	1.55	1.59	1.59	-	-
Ammonium nitrate	1.64 to 1.75	-	-	-	-	-	-	-	-
Binary									
Composition A3	-	1.47	-	-	-	-	-	-	-
Composition B	-	-	-	-	-	-	-		1.66
55/45 Ednatol	-	-	-	-	-	-	-		1.62
75/25 Octol	1.832 to 1.843	-	-	-	-	-	-	-	1.800
70/30 Octol	1.819 to 1.822	-	-	-	-	-	-	-	1.790
50/50 Pentolite	-	-	-	-	-	-	-	-	1.63 to 1.67
Picratol	-	-	-	-	-	-	-	-	1.62
70/30 Tetrytol	-	-	-	-	-	-	-	-	1.60
80/20 Tritonal	-	-	-	-	-	-	-	-	1.73
Ternary									
HBX-1	-	-	-	-	-	-	-	-	1.76
HBX-3	-	-	-	-	-	-	-	-	1.882
Minol-2	-	-	-	-	-	-	-	-	1.62 to 1.74
Torpex	-	-	-	-	-	-	-	-	1.82
Quanternary									
DBX -	-	-	-	-	-	-	-		1.61 to
	-	-	-	-	-	-	-	-	1.74

Table A-6. Conversion Factors and Constants

Unit	Factor	Product
Inches	25.4	Millimeters
Millimeters	0.03937	Inches
Microns	0.001	Millimeters
Angstrom units	0.0000001	Millimeters
Square inches	645.16	Square millimeters
Square millimeters	0.00155	Square inches
Cubic inches	16.387	Milliliters
Milliliters	0.061025	Cubic inches
Cubic feet	0.028317	Cubic meters
Cubic feet	7.48	U.S. gallons
Cubic meters	35.315	Cubic feet
Liters	61.022	Cubic inches
Liters	0.264178	U.S. gallons
U.S. gallons	231.	Cubic inches
U.S. gallons	3.78533	Liters
U.S. gallons	8.337	Pounds water at 150C
Kilograms	2.2046	Pounds
Pounds	453.59	Grams
Ounce	28.35	Grams
Calories	4.1855	International joules
Calories	0.0413	Liter-atmospheres
Kilogram-calories	3.9685	BTU's
BTU's	0.25198	Kilogram-calories
BTU per cubic foot	890.	Kilogram calories per cubic meter
Kilograms per square centimeter	14.223	Pounds per square inch
Atmospheres	1033.3	Grams per square centimeter
Atmospheres	14.696	Pounds per square inch
Atmospheres	760.	Millimeters of mercury
Pounds per square inch	6.895	Kilopascals
Gram moles	22.414	Liters at 0°C and 760 mm of mercury
R (gas constant)	1.9684	Calories per °C per mole
Foot candles	1.	Lumens per square foot
Lumens	0.001496	Watts

Table A-7. Specifications[1]

Material	Specification Number
Primary explosives	
Lead azide	MIL-L-3055
Special purpose lead azide	MIL-L-14758
RD1333 (lead azide)	MIL-L-46225
Mercury fulminate	JAN-M-219
Diazodinitrophenol	JAN-D-552
Lead styphnate, basic	MIL-L-16355
Lead styphnate, normal	MIL-L-757
Tetracene	MIL-T-46938
Potassium dinitrobenzofuroxane	MIL-P-50486
Lead mononitroresorcinate	MIL-L-46496
Aliphatic nitrate esters	
Butanetriol trinitrate	no specification
Diethyleneglycol dinitrate	no specification
Nitrocellulose	MIL-N-244
Nitroglycerin	MIL-N-246
Nitrostarch	no specification
PETN	MIL-P-387
TEGN	no specification
TMETN	no specification
Nitramines	
HMX	MIL-H-45444
RDX	MIL-R-398
EDDN	no specification
Haleite	no specification
NQ	MIL-N-494
Tetryl	MIL-T-339
Nitroaromatics	
Ammonium picrate	MIL-A-166
DATB	no specification
HNAB	no specification
HNS	no specification
TATB	no specification
TNT	MIL-T-248
Ammonium nitrate	MIL-A-50460
Binary	
Amatol	no specification
Composition A3	MIL-C-440
Composition A4	MIL-C-440
Composition A5	MIL-E-14970
Composition A6	MIL-C-60051
Composition B	MIL-C-401
Composition B3	MIL-C-45113
Composition B4	MIL-C-46652
Cyclotol	MIL-C-13477
Composition CH6	MIL-C-21723

Table A-7. Specifications[1]

Material	Specification Number
Ednatol	no specification
Octol	MIL-0-45445
Pentolite (50/50)	JAN-P-408
Picratols	no specification
Tetrytols	no specification
Tritonal	no specification
Ternary	
Amatex	no specification
Ammonal	no specification
H6	MIL-E-22267
HBX	MIL-E-22267
HTA-3	no specification
Minol-2	MIL-M-14745
Torpex	no specification
PBX	
Military specifications	
LX-14-0	MIL-H-48358
PBX Type 1	MIL-P-14999
PBX Type 2	
PBX 0280	MIL-R-48878
PBX 9010	MIL-P-45447
PBX 9407	MIL-R-63419
PBXN-203	MIL-E-85113
PBXN-4	MIL-P-23625
PBXN-5	MIL-E-81111
Navy specifications (ternary category)	
PBXN-3	OS-11641
PBXN-6	WS-12604
PBXN-101	WS-3829
PBXN-102	WS-3823
PBXN-103	OS-12800D
PBXN-104	WS-11511
PBXN-201	WS-1 1498
PBXN-301	WS-12612
Dept. of energy specifications (Lawrence Livermore Laboratory [LLNL])	
LX-04	RM 252353
LX-07	RM 253379
LX-09	RM 253200
LX-10	RM 253511
LX-13	RM 253520

[1]Currently, because of worker exposure hazards, benzene is being replaced by other solvents in all specifications.

Table A-8. Hazardous Component Safety Data Sheet (HCSDS) Numbers

Material	Sheet Number
Amatex	00920
Amatol	00774
Ammonium nitrate	00252
Ammonium picrate	00905
Black powder	00020
Colored smoke (green, yellow, red, violet)	20016
Composition A3	00150
Composition A4	00311
Composition A5	00546
Composition A7	00910
Composition B	00101, 01276, 01277
Composition B4	00151
Composition B5	00413
Composition C4	00077
Composition CH6	00628
Composition H6	00829
Composition HTA-3	00630
DATB	01194
Diazodinitrophenol	40066
Dinitrotoluene	00439
Lead azide (CLA and PVA-LA)	00066
Lead azide RD1333	00128
LX14	01043
Military dynamite	00147
Nitrocellulose	00031
Nitroglycerin	00030
Nitroguanidine	00491
Nitrostarch	40067
Octol	00154
PBXN4	01195
PBXN5	00622
PBXN6	00994
50/50 Pentolite	00253
PETN	00087
Propellant M1	00447
Propellant M2	00807
Propellant M5	00317
Propellant M6	00371
Propellant M7	00221
Propellant M8	00238
Propellant M9	00035
Propellant M10	00601
Propellant M15	00822
Propellant M17	00823
Propellant M30	00318
Pyroxlyn	00860
Tetryl	00116
TMETN	01193
80/20 Tritonal	00479

APPENDIX B

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By Order of the Secretary of the Army:

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General, United States Army
Chief of Staff

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The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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IMPROVISED MUNITIONS HANDBOOK

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IMPROVISED MUNITIONS HANDBOOK

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VI FUSES, DETONATORS & DELAY MECHANISMS

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FRANKFORD ARSENAL

Philadelphia Pennsylvania

INTRODUCTION

1. Purpose and Scope

In Unconventional Warfare operations it may be impossible or unwise to use conventional military munitions as tools in the conduct of certain missions. It may be necessary instead to fabricate the required munitions from locally available or unassuming materials. The purpose of this Manual is to increase the potential of Special Forces and guerrilla troops by describing in detail the manufacture of munitions from seemingly innocuous locally available materials.

Manufactured, precision devices almost always will be more effective, more reliable, and easier to use than improvised ones, but shelf items will just not be available for certain operations for security or logistical reasons. Therefore the operator will have to rely on materials he can buy in a drug or paint store, find in a junk pile, or scrounge from military stocks. Also, many of the ingredients and materials used in fabricating homemade items are so commonplace or innocuous they can be carried without arousing suspicion. The completed item itself often is more easily concealed or camouflaged. In addition, the field expedient item can be tailored for the intended target, thereby providing an advantage over the standard item in flexibility and versatility.

The Manual contains simple explanations and illustrations to permit construction of the items by personnel not normally familiar with making and handling munitions. These items were conceived in-house or, obtained from other publications or personnel engaged in munitions or

special warfare work. This Manual includes methods for fabricating explosives, detonators, propellants, shaped charges, small arms, mortars, incendiaries, delays, switches, and similar items from indigenous materials.

2. Safety and Reliability

Each item was evaluated both theoretically and experimentally to assure safety and reliability. A large number of items were discarded because of inherent hazards or unreliable performance. Safety warnings are prominently inserted in the procedures where they apply but it is emphasized that safety is a matter of attitude. It is a proven fact that men who are alert, who think out a situation, and who take correct precautions have fewer accidents than the careless and indifferent. It is important that work be planned and that instructions be followed to the letter; all work should be done in a neat and orderly manner. In the manufacture explosives, detonators, propellants and incendiaries, equipment must be kept clean and such energy concentrations as sparks,

friction, impact, hot objects, flame, chemical reactions, and excessive pressure should be avoided.

These items were found to be effective in most environments; however, samples should be made and tested remotely prior to actual use of assure proper performance. Chemical items should be used as soon as possible after preparation and kept free of moisture, dirt, and the above energy concentrations. Special care should be taken in any attempt at substitution or use of items for purposes other than that specified or intended.

Section I
No. 1

PLASTIC EXPLOSIVE FILLER

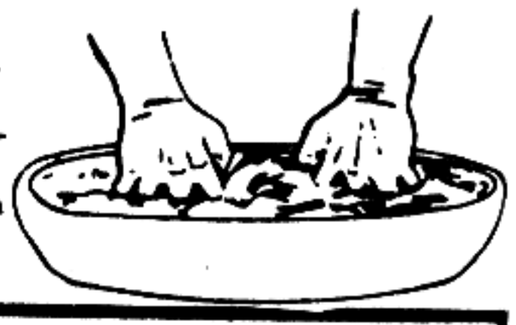
A plastic explosive filler can be made from potassium chlorate and petroleum jelly. This explosive can be detonated with commercial #8 or any military blasting cap.

MATERIAL REQUIRED	HOW USED
Potassium chlorate	Medicine Manufacture of matches
Petroleum jelly (Vaseline)	Medicine Lubricant
Piece of round stick	
Wide bowl or other container for mixing ingredients.	

PROCEDURE

1. Spread potassium chlorate crystals thinly on a hard surface. Roll the round stick over crystals to crush into a very fine powder until it looks like face powder or wheat flour.

2. Place 9 parts powdered potassium chlorate and 1 part petroleum jelly in a wide bowl or similar container. Mix ingredients with hands (knead) until a uniform paste is obtained.



Store explosive in a waterproof container until ready to use.

Section I
6 No. 2

POTASSIUM NITRATE

Potassium nitrate (saltpeter) can be extracted from many natural sources and can be used to make nitric acid, black powder and many pyrotechnics. The yield ranges from .1 to 10% by weight, depending on the fertility of the soil.

MATERIALS

Nitrate bearing earth or other material, about 3-1/2 gallons (13-1/2 liters)

SOURCE

Soil containing old decayed vegetable or animal matter
Old cellars and/or farm dirt floors
Earth from old burial grounds
Decayed stone or mortar building foundations
Totally burned whitish wood ash powder
Totally burned paper (black)

Fine wood ashes, about 1/2 cup (1/8 liter)

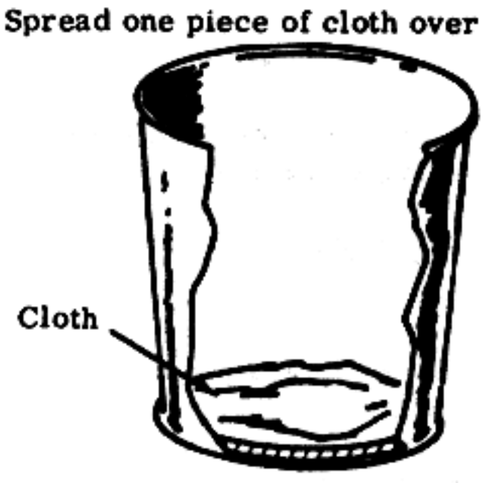
Bucket or similar container, about 5 gallons (19 liters) in volume (Plastic, metal, or wood)
2 pieces of finely woven cloth, each slightly larger than bottom of bucket
Shallow pan or dish, at least as large as bottom of bucket
Shallow heat resistant container (ceramic, metal, etc.)
Water - 1-3/4 gallons (6-3/4 liters)
Awl, knife, screwdriver, or other hole producing instrument
Alcohol about 1 gallon (4 liters) (whiskey, rubbing alcohol, etc.)
Heat source (fire, electric heater, etc.)
Paper
Tape

NOTE: Only the ratios of the amounts of ingredients are important. Thus, for twice as much potassium nitrate, double quantities used.

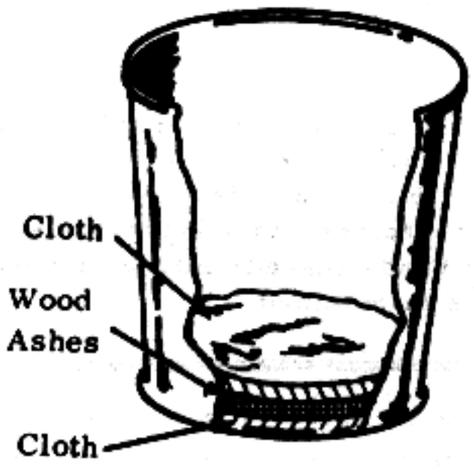
7

PROCEDURE:

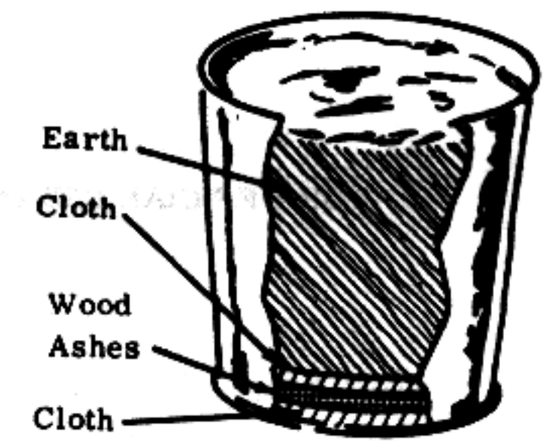
1. Punch holes in bottom of bucket. Spread one piece of cloth over holes inside of bucket.



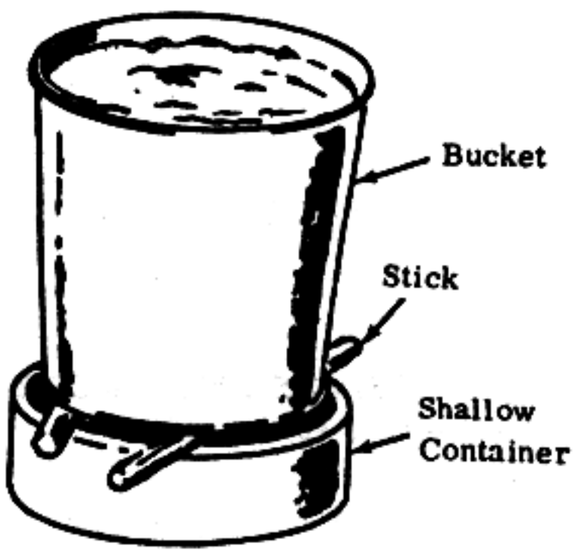
2. Place wood ashes on cloth and spread to make a layer about the thickness of the cloth. Place second piece of cloth on top of ashes.



3. Place dirt in bucket.



4. Place bucket over shallow container. Bucket may be supported on sticks if necessary.



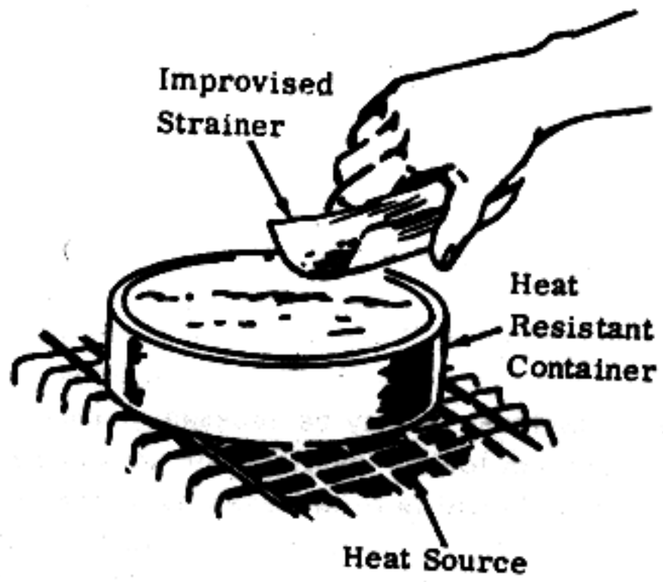
8

5. Boil water and pour it over earth in bucket a little at a time. Allow water to run through holes in bucket into shallow container. Be sure water goes through all of the earth. Allow drained liquid to cool and settle for 1 to 2 hours.

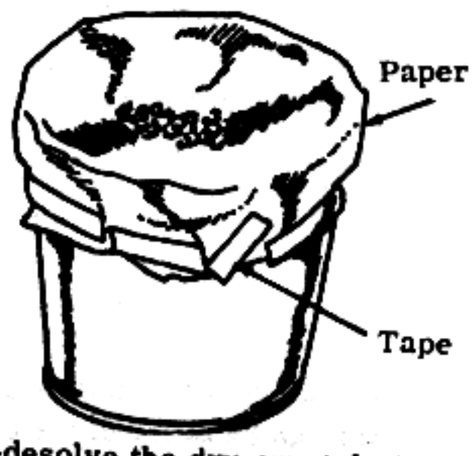
NOTE: Do not pour all of the water at once, since this may cause stoppage.

6. Carefully drain off liquid into heat resistant container. Discard any sludge remaining in bottom of the shallow container.

7. Boil mixture over hot fire for at least 2 hours. Small grains of salt will begin to appear in the solution. Scoop these out as they form, using any type of improvised strainer (paper, etc.).



8. When liquid has boiled down to approximately half its original volume, remove from fire and let sit. After half an hour add an equal volume of alcohol. When mixture is poured through paper, small white crystals will collect on top of it.



9. To purify the potassium nitrate, re-desolve the dry crystals in the smallest possible amount of boiled water. Remove any salt crystals that appear (Step 7); pour through an improvised filter made of several pieces of paper and evaporate or gently heat the concentrated solution to dryness.

10. Spread crystals on flat surface and allow to dry. The potassium nitrate crystals are now ready for use.

Section I
9 No. 4
NITRIC ACID

Nitric acid is used in the preparation of many explosives, incendiary mixtures, and acid delay timers. It may be prepared by distilling a mixture of potassium nitrate and concentrated sulfuric acid.

MATERIAL REQUIRED:

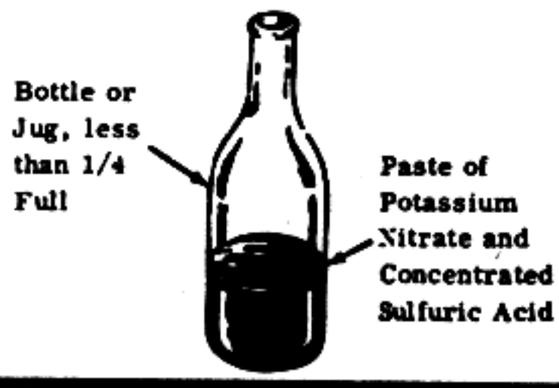
- Potassium nitrate (2 parts by volume) — Drug Store
- Concentrated sulfuric acid (1 part by volume) — Improvised (Section I, No. 2) Motor vehicle batteries Industrial plants
- 2 bottles or ceramic jugs (narrow necks are preferable)
- Pot or frying pan
- Heat source (wood, coal, or charcoal)
- Tape (paper, electrical, masking, etc. but not cellophane)
- Paper or rags

IMPORTANT: If sulfuric acid is obtained from a motor vehicle battery, concentrate it by boiling it until white fumes appear. DO NOT INHALE FUMES.

NOTE: The amount of nitric acid produced is the same as the amount of potassium nitrate. Thus, for 2 tablespoonsful of nitric acid, use 2 tablespoonsful of potassium nitrate and 1 tablespoonsful of concentrated sulfuric acid.

PROCEDURE:

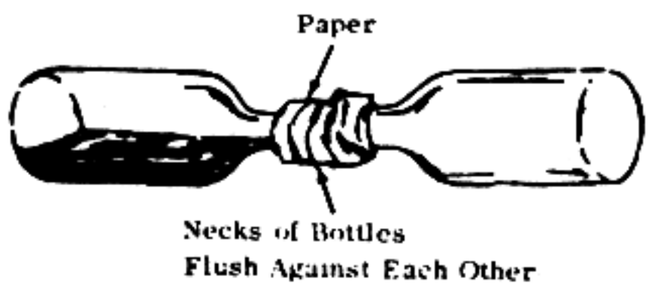
1. Place dry potassium nitrate in bottle or jug. Add sulfuric acid. Do not fill bottle more than 1/4 full. Mix until paste is formed.



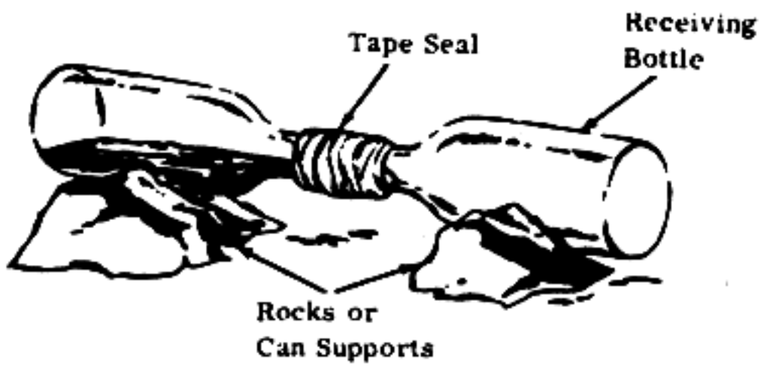
CAUTION: Sulfuric acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Fumes are also dangerous and should not be inhaled.

10

2. Wrap paper or rags around necks of 2 bottles. Securely tape necks of bottles together. Be sure bottles are flush against each other and that there are no air spaces.

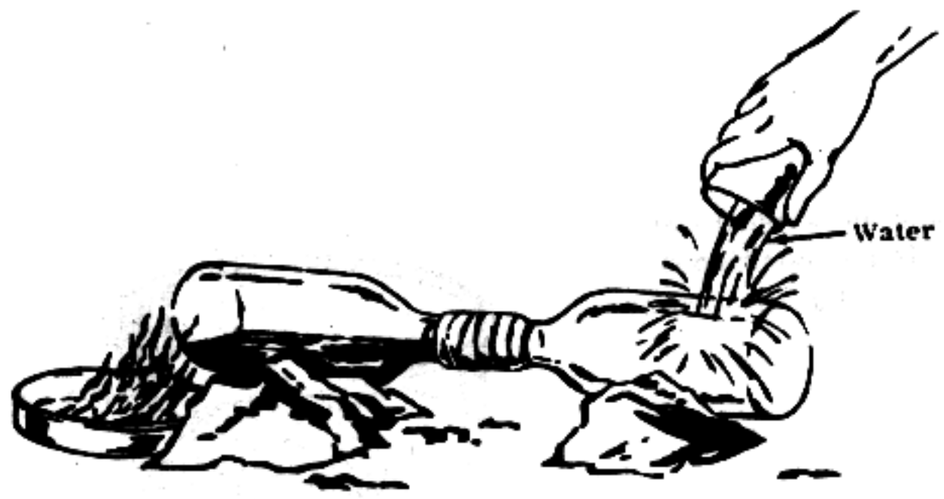


3. Support bottles on rocks or cans so that empty bottle is slightly lower than bottle containing paste so that nitric acid that is formed in receiving bottle will not run into other bottle.



4. Build fire in pot or frying pan.

5. Gently heat bottle containing mixture by moving fire in and out. As red fumes begin to appear periodically pour cool water over empty receiving bottle. Nitric acid will begin to form in the receiving bottle.



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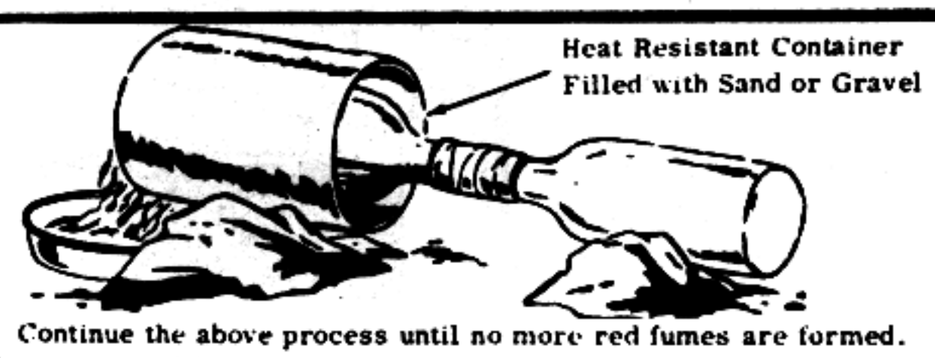
CAUTION: Do not overheat or wet bottle containing mixture or it may shatter. As an added precaution, place bottle to be heated in heat resistant container filled with sand or gravel. Heat this outer container to produce nitric acid.



6. Continue the above process until no more red fumes are formed. If the nitric acid formed in the receiving bottle is not clear (cloudy) pour it into cleaned bottle and repeat Steps 2 - 6.

CAUTION: Nitric acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Fumes are also dangerous and should not be inhaled.

Nitric acid should be kept away from all combustibles and should be kept in a sealed ceramic or glass container.

Section I
12 No. 5
INITIATOR FOR DUST EXPLOSIONS

An initiator which will initiate common material to produce dust explosions can be rapidly and easily constructed. This type of charge is ideal for the destruction of enclosed areas such as rooms or buildings.

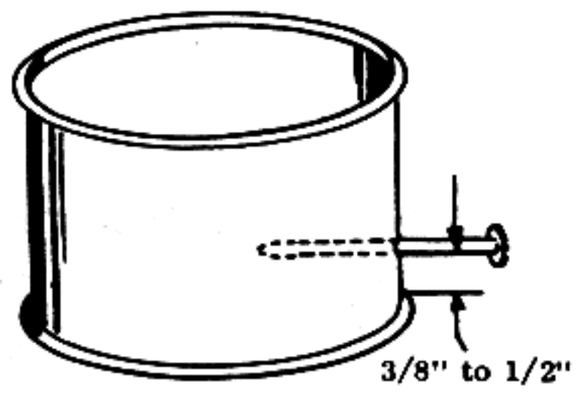
MATERIAL REQUIRED:

A flat can, 3 in. (8 cm) diameter and 1-1/2 in. (3-3/4 cm) high. A 6-1/2 ounce Tuna can serves the purpose quite well.
Blasting cap
Explosive
Aluminum (may be wire, cut sheet, flattened can or powder
Large nail, 4 in. (10 cm) long
Wooden rod - 1/4 in. (6 mm) diameter
Flour, gasoline and powder or chipped aluminum

NOTE: Plastic explosives (Comp. C-4, etc.) produce better explosions than cast explosives (Comp. B, etc.).

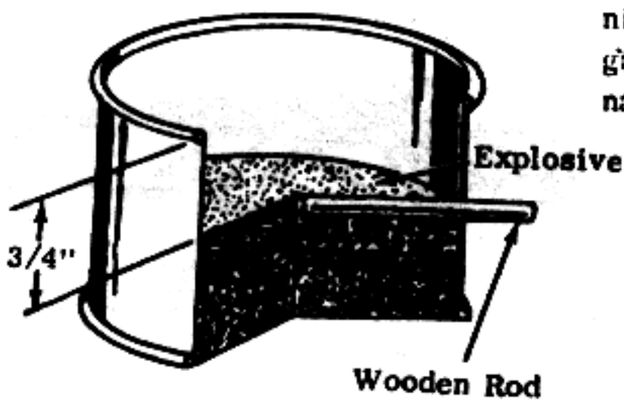
PROCEDURE:

1. Using the nail, press a hole through the side of the Tuna can 3/8 to 1/2 inch (1 to 1-1/2 cm) from the bottom. Using a rotating and lever action, enlarge the hole until it will accommodate the blasting cap.



2. Place the wooden rod in the hole and position the end of the rod at the center of the can.

3. Press explosive into the can, being sure to surround the rod, until it is 3/4 inch (2 cm) from top of the can. Carefully remove the wooden rod.



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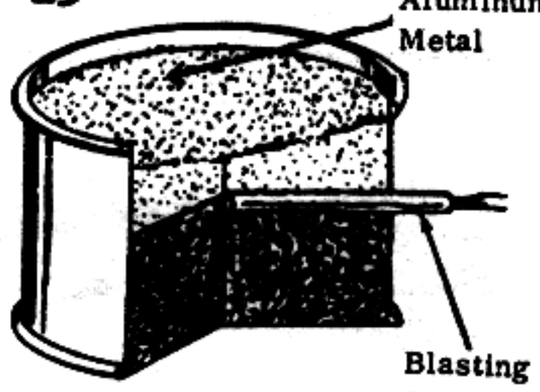
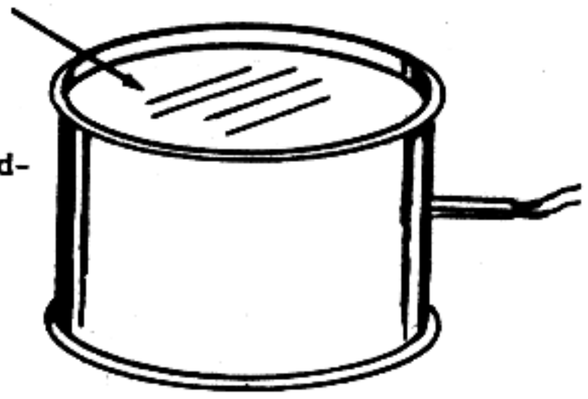
4. Place the aluminum metal on top of the explosive.

5. Just before use, insert the blasting cap into the cavity made by the rod. The initiator is now ready for use.



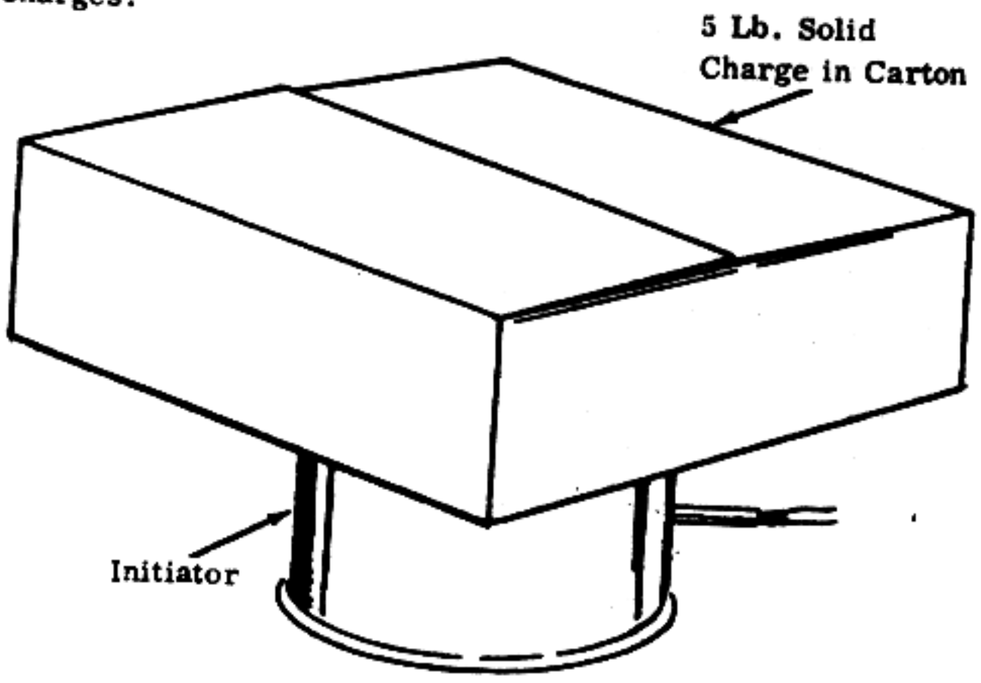


NOTE: If it is desired to carry the initiator some distance, cardboard may be pressed on top of the aluminum to insure against loss of material.

HOW TO USE:

This particular unit works quite well to initiate charges of five pounds of flour, 1/2 gallon (1-2/3 liters) of gasoline or two pounds of flake painters aluminum. The solid materials may merely be contained in sacks or cardboard cartons. The gasoline may be placed in plastic-coated paper milk cartons, plastic or glass bottles. The charges are placed directly on top of the initiator and the blasting cap is actuated electrically or by fuse depending on the type of cap employed. This will destroy a 2,000 cubic feet enclosure (building 10 x 20 x 10 feet).

NOTE: For larger enclosures, use proportionately larger initiators and charges.



Section I

14 No. 6

FERTILIZER EXPLOSIVE

An explosive munition can be made from fertilizer grade ammonium nitrate and either fuel oil or a mixture of equal parts of motor oil and gasoline. When properly prepared, this explosive munition can be detonated with a blasting cap.

MATERIAL REQUIRED:

Ammonium nitrate (not less than 32% nitrogen)
Fuel oil or gasoline and motor oil (1:1 ratio)
Two flat boards. (At least one of these should be comfortably held in the hand, i.e. 2 x 4 and 36 x 36.)
Bucket or other container for mixing ingredients
Iron or steel pipe or bottle, tin can or heavy-walled cardboard tube
Blasting cap
Wooden rod - 1/4 in. diameter
Spoon or similar measuring container

PROCEDURE:

1. Spread a handful of the ammonium nitrate on the large flat board and rub vigorously with the other board until the large particles are crushed into a very fine powder that looks like flour (approx. 10 min).

NOTE: Proceed with Step 2 as soon as possible since the powder may take moisture from the air and become spoiled.

2. Mix one measure (cup, tablespoon, etc.) of fuel oil with 16 measures of the finely ground ammonium nitrate in a dry bucket or other suitable container and stir with the wooden rod. If fuel oil is not available, use one half measure of gasoline and one half measure of motor oil. Store in a waterproof container until ready to use.

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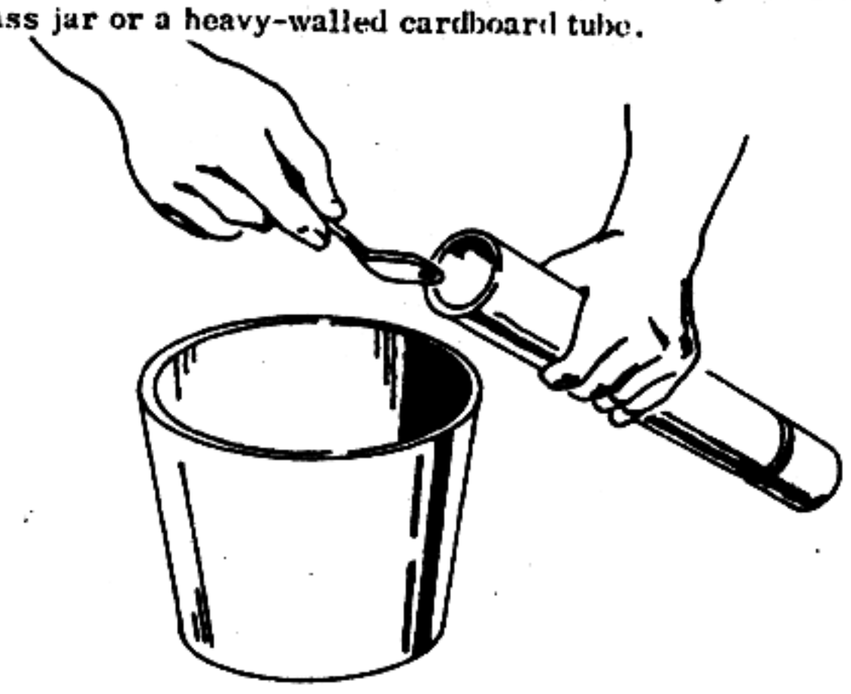
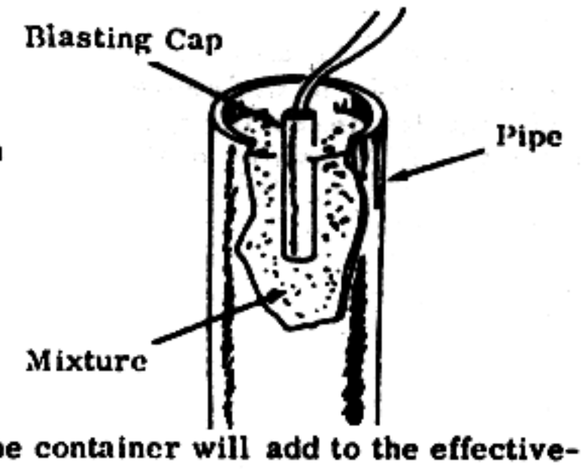
3. Spoon this mixture into an iron or steel pipe which has an end cap threaded on one end. If a pipe is not available, you may use a dry tin can, a glass jar or a heavy-walled cardboard tube.



NOTE: Take care not to tamp or shake the mixture in the pipe. If mixture becomes tightly packed, one cap will not be sufficient to initiate the explosive.

4. Insert blasting cap just beneath the surface of the explosive mix.



NOTE: Confining the open end of the container will add to the effectiveness of the explosive.

Section I
16 No. 9
"RED OR WHITE POWDER" PROPELLANT

"Red or White Powder" Propellant may be prepared in a simple, safe manner. The formulation described below will result in approximately 2-1/2 pounds of powder. This is a small arms propellant and should only be used in weapons with 1/2 in. inside diameter or less, such as the Match Gun or the 7.62 Carbine, but not pistols.

MATERIAL REQUIRED:

Heat source (Kitchen stove or open fire)
2 gallon metal bucket
Measuring cup (8 ounces)
Wooden spoon or rubber spatula
Metal sheet or aluminum foil (at least 18 in. sq.)
Flat window screen (at least 1 ft. sq.)
Potassium nitrate (granulated) 2-1/3 cups
White sugar (granulated) 2 cups
Powdered ferric oxide (rust) 1/8 cup (if available)
Clear water, 3-1/2 cups

PROCEDURE:

1. Place the sugar, potassium nitrate, and water in the bucket. Heat with a low flame, stirring occasionally until the sugar and potassium nitrate dissolve.

2. If available, add the ferric oxide (rust) to the solution. Increase the flame under the mixture until it boils gently.

NOTE: The mixture will retain the rust coloration.

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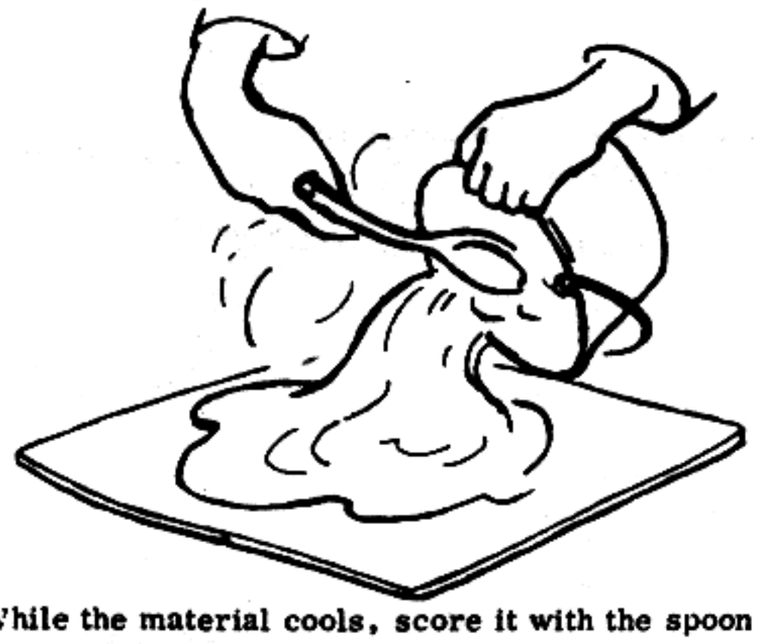
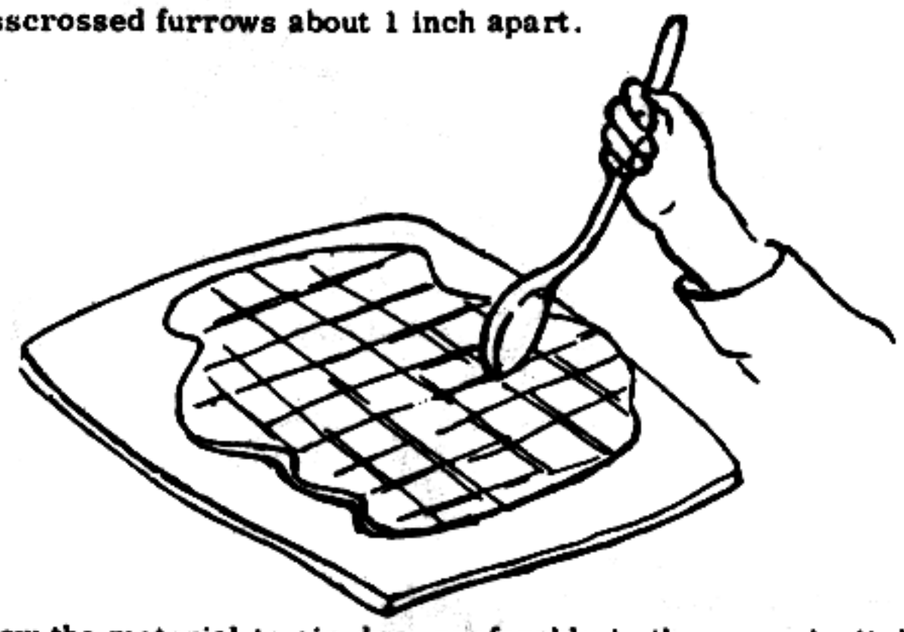
3. Stir and scrape the bucket sides occasionally until the mixture is reduced to one quarter of its original volume, then stir continuously.

4. As the water evaporates, the mixture will become thicker until it reaches the consistency of cooked breakfast cereal or homemade fudge. At this stage of thickness, remove the bucket from the heat source, and spread the mass on the metal sheet.



5. While the material cools, score it with the spoon or spatula in crisscrossed furrows about 1 inch apart.



6. Allow the material to air dry, preferably in the sun. As it dries, rescore it occasionally (about every 20 minutes) to aid drying.

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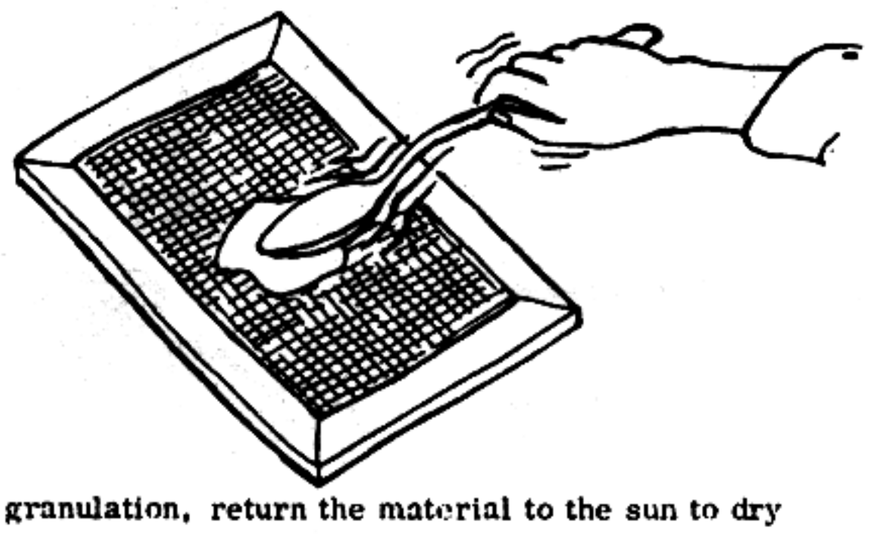
7. When the material has dried to a point where it is moist and soft but not sticky to the touch, place a small spoonful on the screen. Rub the material back and forth against the screen mesh with spoon or other flat object until the material is granulated into small worm-like particles.



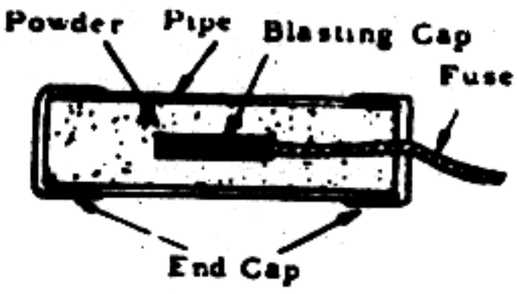
8. After granulation, return the material to the sun to dry completely.

Section II
19 No. 1
PIPE HAND GRENADE

Hand grenades can be made from a piece of iron pipe. The filler can be plastic or granular military explosive, improvised explosive, or propellant from shotgun or small arms ammunition. ●

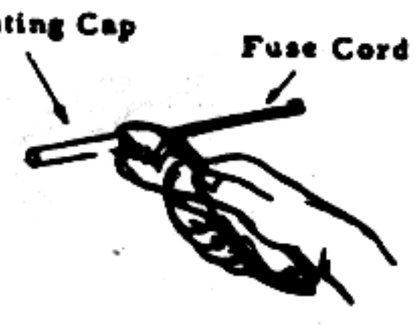
MATERIAL REQUIRED

Iron pipe, threaded ends, 1 1/2" to 3" diam., 3" to 8" long.
Two (2) iron pipe caps.
Explosive or propellant
Nonelectric blasting cap. (Commercial or military)
Fuse cord
Hand drill
Pliers



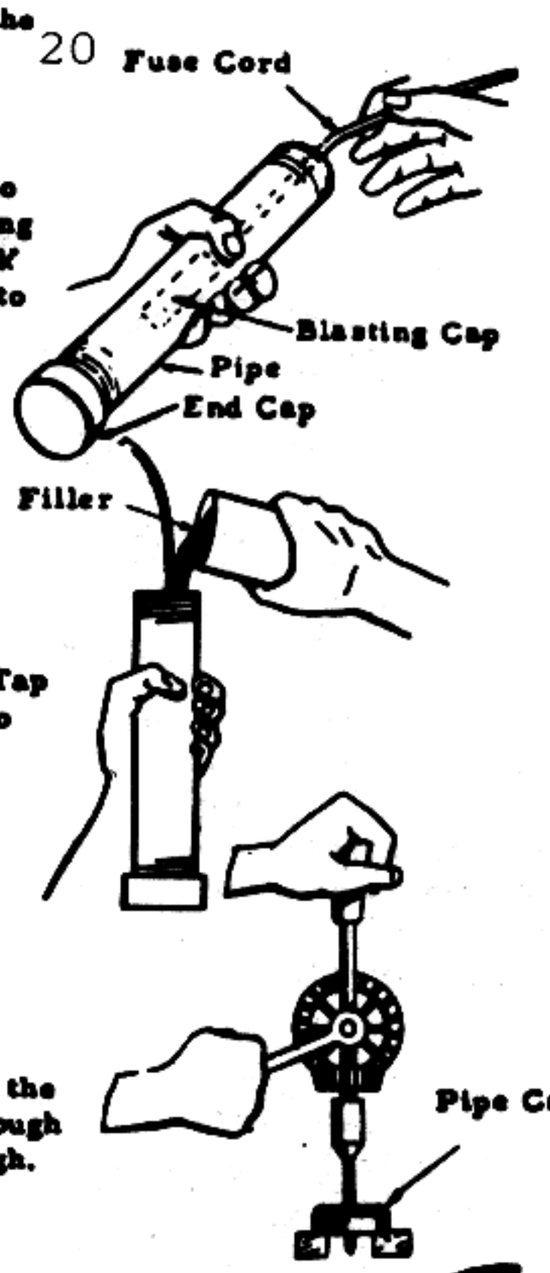
PROCEDURE

1. Place blasting cap on one end of fuse cord and crimp with pliers.



NOTE: To find out how long the fuse cord should be, check the time it takes a known length to burn. If 12 inches burns in 30 seconds, a 6-inch cord will ignite the grenade in 15 seconds.

2. Screw pipe cap to one end of pipe. Place fuse cord with blasting cap into the opposite end so that the blasting cap is near the center of the pipe.



NOTE: If plastic explosive is to be used, fill pipe before inserting blasting cap. Push a round stick into the center of the explosive to make a hole and then insert the blasting cap.

3. Pour explosive or propellant into pipe a little bit at a time. Tap the base of the pipe frequently to settle filler.

4. Drill a hole in the center of the unassembled pipe cap large enough for the fuse cord to pass through.

5. Wipe pipe threads to remove any filler material.

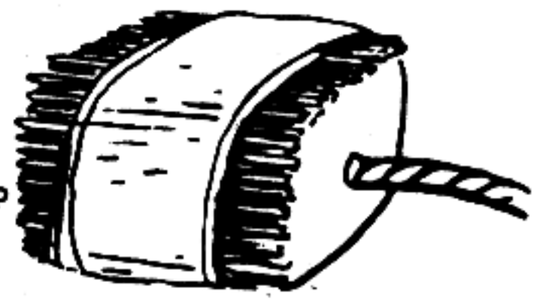
Slide the drilled pipe cap over the fuse and screw handtight onto the pipe.

NAIL GRENADE

Effective fragmentation grenades can be made from a block of TNT or other blasting explosive and nails

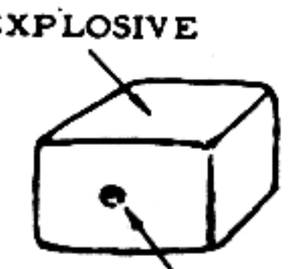
MATERIAL REQUIRED:

Block of TNT or other blasting explosive
Nails
Non-Electric Military blasting cap
Fuse Cord
Tape, sting, wire or glue

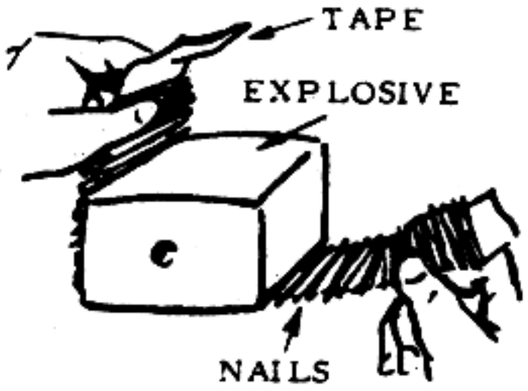


PROCEDURE:

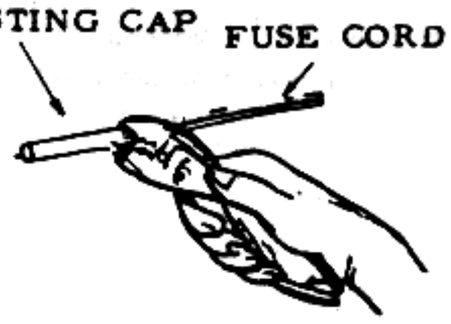
1. If an explosive charge other than a standard TNT block is used, make a hole in the center of the charge for inserting the blasting cap. TNT can be drilled with relative safety. With plastic explosives, a hole can be made by pressing a round stick into the center of the charge. The hole should be deep enough that the blasting cap is totally within the explosive.



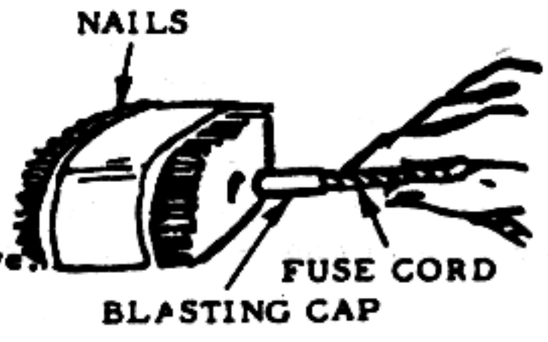
2. Tape, tie or glue one or two rows of closely packed nails to sides of explosive block. Nails should completely cover the four surfaces of the block.



3. Place blasting cap on one end of the fuse cord and crimp with pliers.



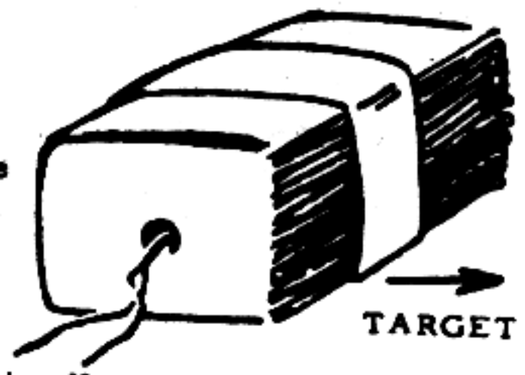
NOTE: To find out how long the fuse cord should be, check the time it takes a known length to burn. If 12 inches (30 cm) burns for 30 seconds, a 10 second delay will require a 4 inch (10 cm) fuse.



4. Insert the blasting cap in the hole in the block of explosive. Tape or tie fuse cord securely in place so that it will not fall out when the grenade is thrown.

ALTERNATE USE:

An effective directional anti-personnel mine can be made by placing nails on only one side of the explosive block. For this case, an electric blasting cap can be used.



WINE BOTTLE CONE CHARGE

This cone charge will penetrate 3 to 4 inches of armor. Placed on an engine or engine compartment it will disable a tank or other vehicle.

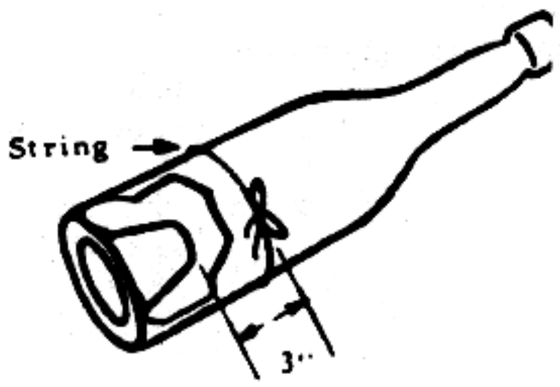
MATERIAL REQUIRED:

Glass wine bottle with false bottom (cone shaped)
Plastic or castable explosive
Blasting cap
Gasoline or Kerosene (small amount)
String
Adhesive tape

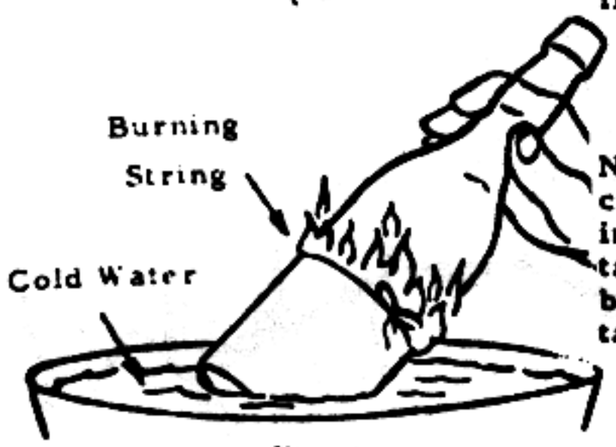
PROCEDURE:

1. Soak a piece of string in gasoline or kerosene. Double wrap this string around the wine bottle approximately 3 in. (7 1/2 cm) above the top of the cone.

NOTE: A small amount of motor oil added to the gasoline or kerosene will improve results.

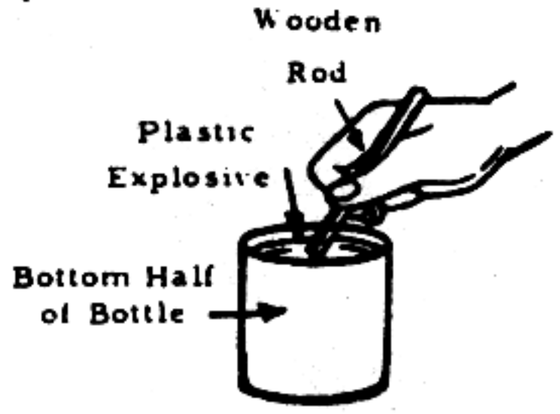


2. Ignite the string and allow to burn for 1 to 2 minutes. Then plunge the bottle into cold water to crack the bottle. The top half can now be easily removed and discarded.



3. If plastic explosive is used:
(a) pack explosive into the bottle a little at a time compressing with a wooden rod. Fill the bottle to the top.

(b) press a 1/4 in. wooden dowel 1/2 in. (12mm) into the middle of the top of the explosive charge to form a hole for the blasting cap.



4. If TNT or other castable explosive is used:
(a) break explosive into small pieces using a wooden mallet or non-sparking metal tools. Place pieces in a tin can.

(b) Suspend this can in a larger container which is partly filled with water. A stiff wire or stick pushed through the smaller can will accomplish this.

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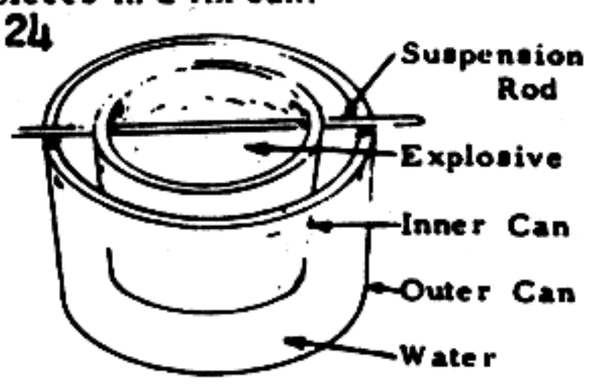


CAUTION: The inner can must not rest on the bottom of the outer container.

(c) Heat the container on an electric hot plate or other heat source. Stir the explosive frequently with a wooden stick while it is melting.

CAUTION: Keep area well ventilated while melting explosive. Fumes may be poisonous.

(d) When all the explosive has melted, remove the inner container and stir the molten explosive until it begins to thicken. During this time the bottom half of the wine bottle should be placed in the container of hot water. This will pre-heat the bottle so that it will not crack when the explosive is poured.

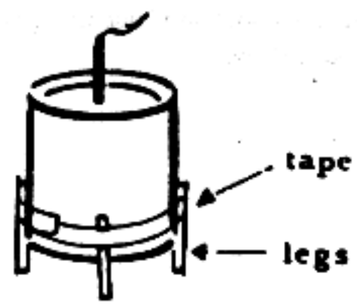
(e) Remove the bottle from hot water and dry thoroughly. Pour molten explosive into the bottle and allow to cool. The crust which forms on top of the charge during cooling should be broken with a wooden stick and more explosive added. Do this as often as necessary until the bottle is filled to the top.

(f) When explosive has completely hardened, bore a hole for the blasting cap in the middle of the top of the charge about 1/2 in. (12mm) deep.

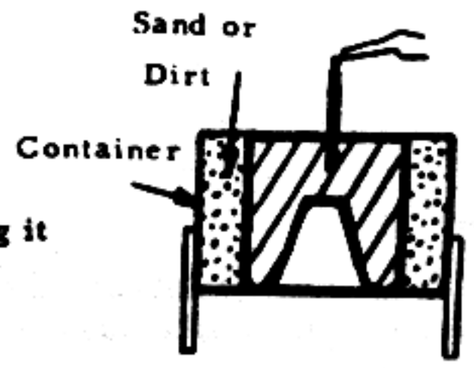
HOW TO USE:

1. Place blasting cap in the hole in the top of the charge. If non-electric cap is used be sure cap is crimped around fuze and fuze is long enough to provide safe delay.

2. Place the charge so that the bottom is 3 to 4 in. (7 1/2 to 10 cm) from the target. This can be done by taping legs to the charge or any other convenient means as long as there is nothing between the base of the charge and the target.



3. If electric cap is used, connect blasting cap wires to firing circuit.



NOTE: The effectiveness of this charge can be increased by placing it inside a can, box, or similar container and packing sand or dirt between the charge and the container.

Section II
25 No. 4

GRENADE-TIN CAN LAND MINE

This device can be used as a land mine that will explode when the trip wire is pulled.

MATERIAL REQUIRED:

Hand grenade having side safety lever
Sturdy container, open at one end, that is just large enough to fit over grenade and its safety lever (tin can of proper size is suitable).
Strong string or wire

NOTE: The container must be of such a size that, when the grenade is placed in it and the safety pin removed, its sides will prevent the safety lever from springing open. One end must be completely open.

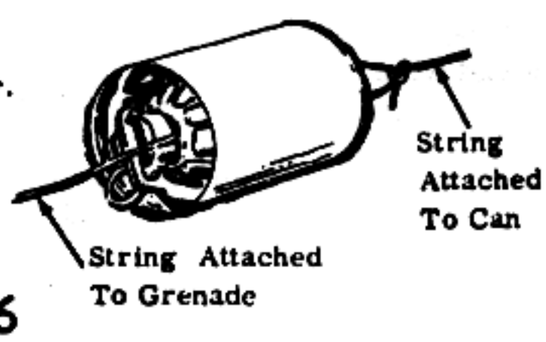
PROCEDURE:

1. Fasten one piece of string to the closed end of container, making a strong connection. This can be done by punching 2 holes in the can, looping the string through them, and tying a knot.

2. Tie free end of this string to bush, stake, fencepost, etc.

3. Fasten another length of string to the grenade such that it cannot interfere with the functioning of the ignition mechanism of the grenade.

4. Insert grenade into container.



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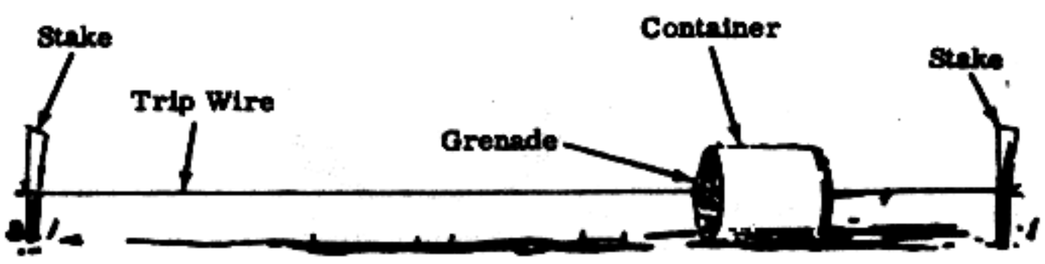
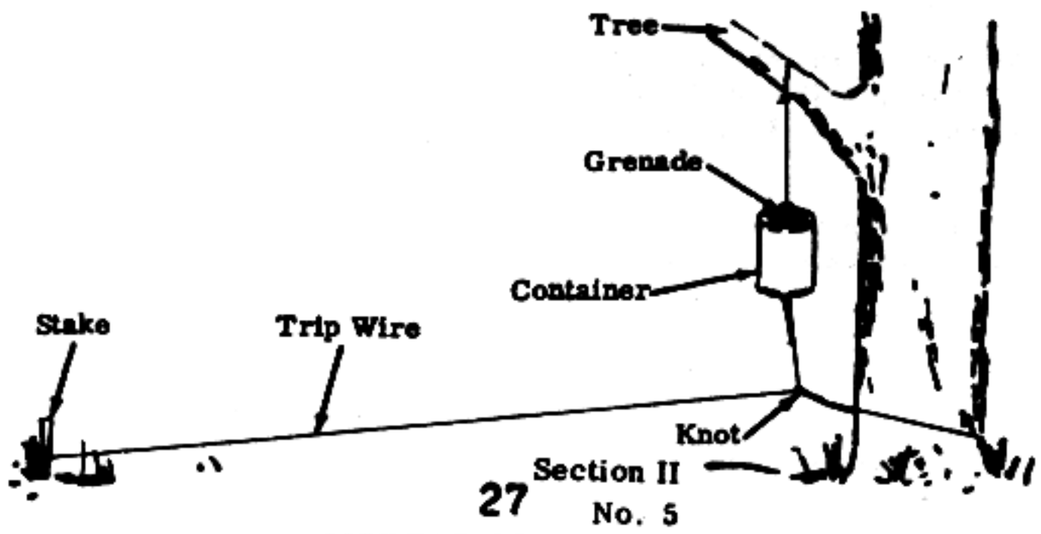
5. Lay free length of string across path and fasten to stake, bush, etc. The string should remain taut.



HOW TO USE:

1. Carefully withdraw safety pin by pulling on ring. Be sure safety lever is restrained during this operation. Grenade will function in normal manner when trip wire is pulled.

NOTE: In areas where concealment is possible, a greater effect may be obtained by suspending the grenade several feet above ground, as illustrated below.



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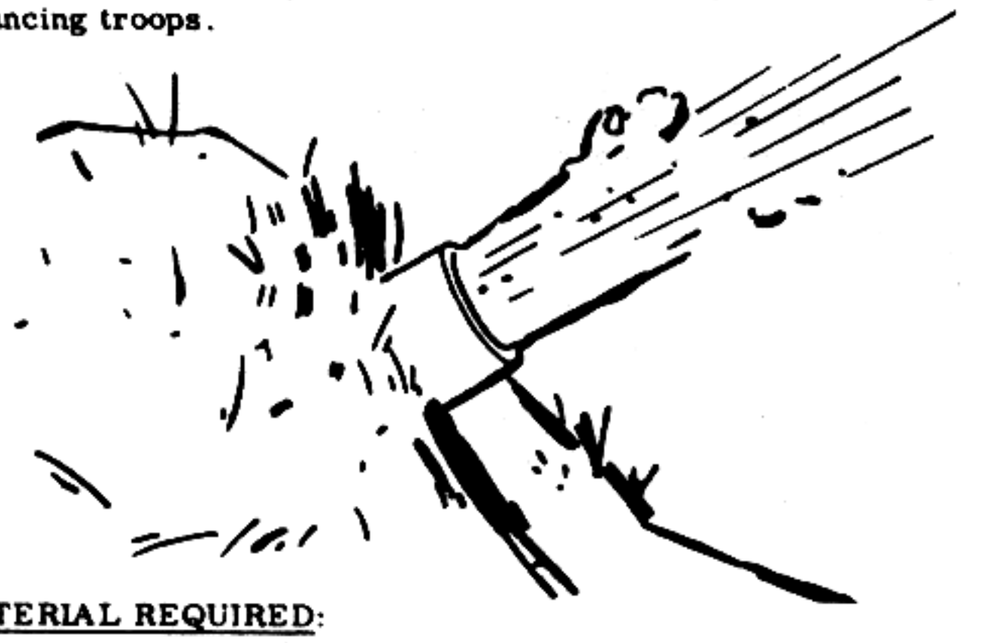
Section II
No. 5

MORTAR SCRAP MINE

A directional shrapnel launcher that can be placed in the path of advancing troops.



MATERIAL REQUIRED:

Iron pipe approximately 3 ft. (1 meter) long and 2 in. to 4 in. (5 to 10 cm) in diameter and threaded on at least one end. Salvaged artillery cartridge case may also be used.
Threaded cap to fit pipe.
Black powder or salvaged artillery propellant about 1/2 lb. (200 gms) total.
Electrical igniter (commercial SQUIB or improvised igniter, Section VI, No. 1). Safety or improvised fuse may also be used.
Small stones about 1 in. (2-1/2 cm) in diameter or small size scrap; about 1 lb. (400 gms) total.
Rags for wadding, each about 20 in. by 20 in. (50 cm x 50 cm)
Paper or bag
Battery and wire
Stick (non-metallic)

Note: Be sure pipe has no cracks or flaws.

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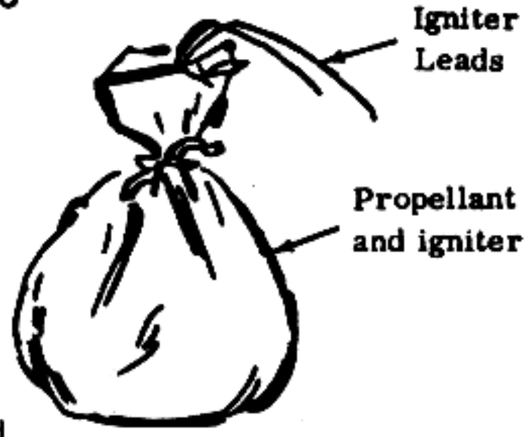
PROCEDURE:

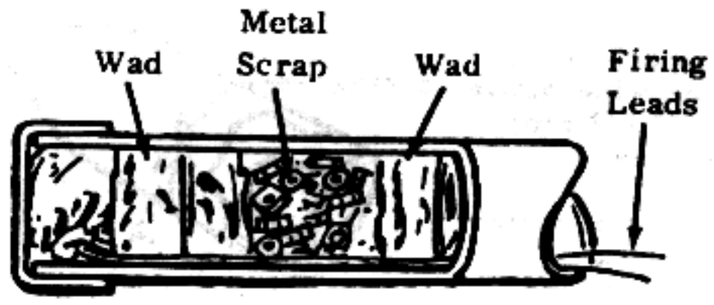
1. Screw threaded cap onto pipe.



2. Place propellant and igniter in paper or rag and tie package with string so contents will not fall out.

3. Insert packaged propellant and igniter into pipe until package rests against threaded cap leaving firing leads extending from open end of pipe.
4. Roll rag till it is about 6 in. (15-1/2 cm) long and the same diameter as pipe. Insert rag wadding against packaged propellant igniter. With caution, pack tightly using stick.
5. Insert stones and/or scrap metal into pipe.

6. Insert second piece of rag wadding against stones and/or metal scrap. Pack tightly as before.



HOW TO USE:

1. Bury pipe in ground with open end facing the expected path of the enemy. The open end may be covered with cardboard and a thin layer of dirt or leaves as camouflage.

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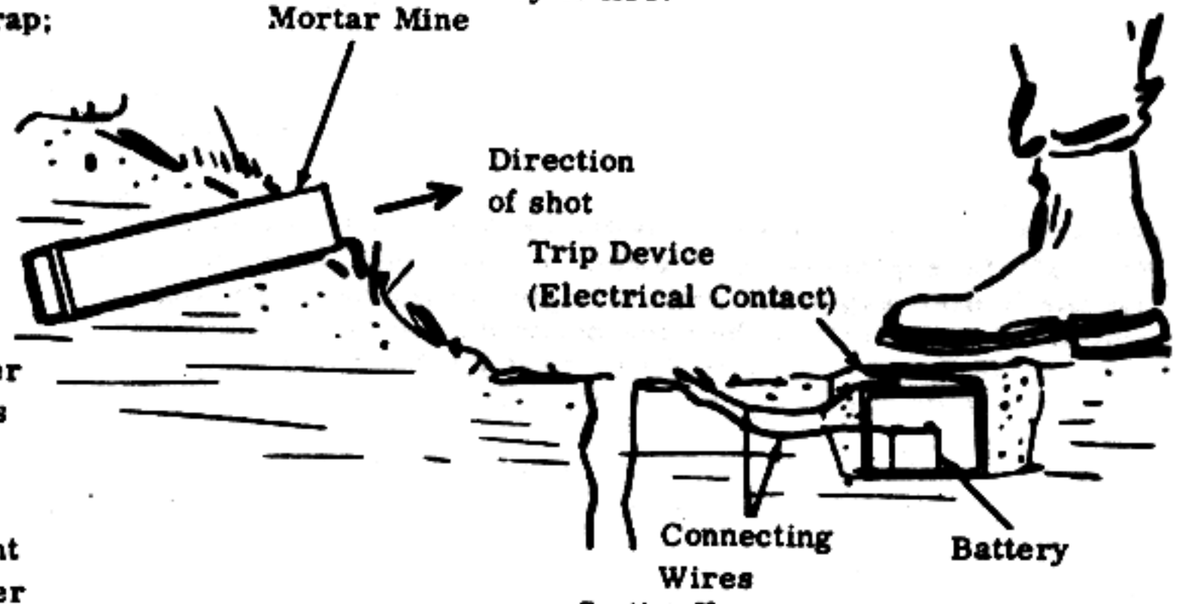
2. Connect firing leads to battery and switch. Mine can be remotely fired when needed or attached to trip device placed in path of advancing troops.

NOTE: A NON-ELECTRICAL ignition system can be substituted for the electrical ignition system as follows.

1. Follow above procedure, substituting safety fuse for igniter.
2. Light safety fuse when ready to fire.

Mortar Mine



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Section II
No. 6

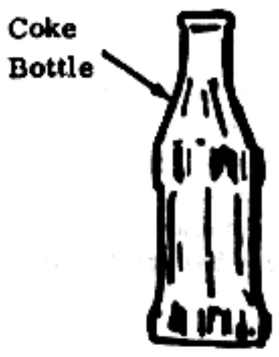
COKE BOTTLE SHAPED CHARGE

This shaped charge will penetrate 3 in. (7-1/2 cm) of armor. (It will disable a vehicle if placed on the engine or engine compartment).

MATERIAL REQUIRED:

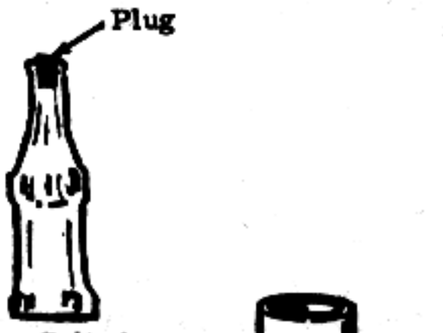
Glass Coke bottle, 6-1/2 oz. size
Plastic or castable explosive, about 1 lb. (454 gm)

Blasting cap
Metal cylinder, open at both ends, about 6 in. (15 cm) long and 2 in. (5 cm) inside diameter. Cylinder should be heavy walled for best results.
Plug to fit mouth of coke bottle (rags, metal, wood, paper, etc.)
Non-metal rod about 1/4 in. (6 mm) in diameter and 8 in. (20 cm) or more in length.
Tape or string
2 tin cans if castable explosive is used (See Section II, No. 3)

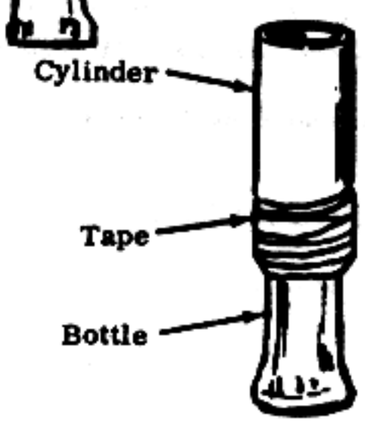


NOTE: Cylinder may be cardboard, plastic, etc. if castable explosive is used.

PROCEDURE:



1. Place plug in mouth of bottle.



2. Place cylinder over top of bottle until bottom of cylinder rests on widest part of bottle. Tape cylinder to bottle. Container should be straight on top of bottle.

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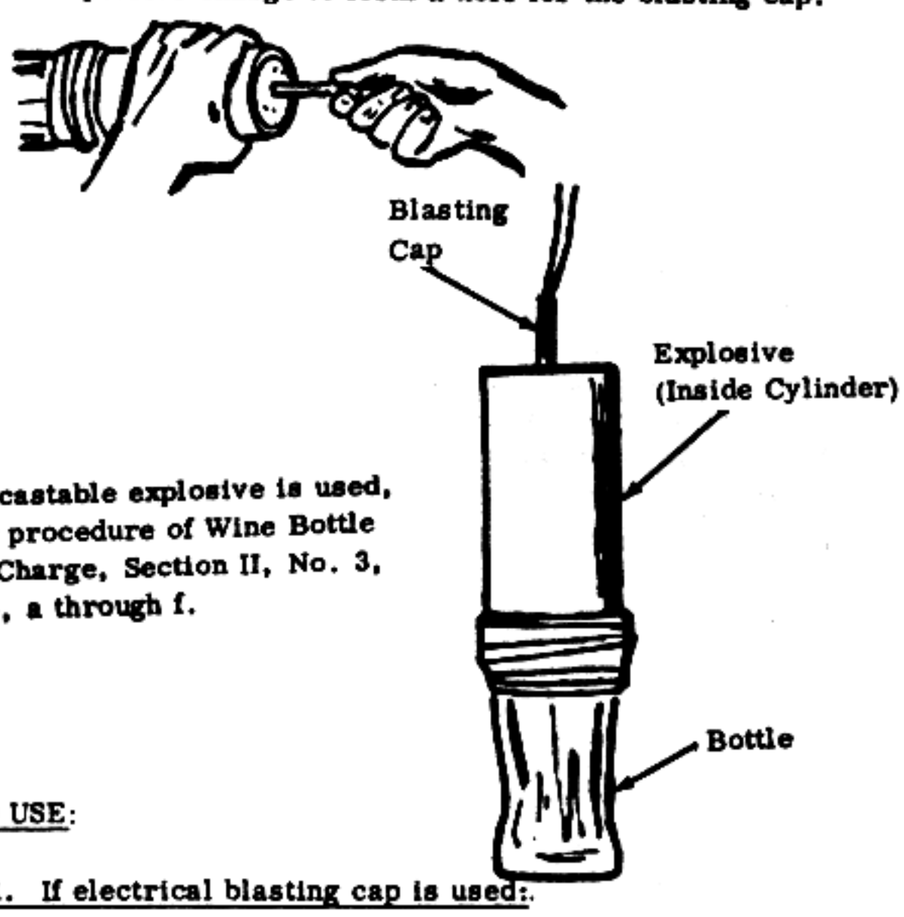
3. If plastic explosive is used:

a. Place explosive in cylinder a little at a time tamping with rod until cylinder is full.

b. Press the rod about 1/2 in. (1 cm) into the middle of the top of the explosive charge to form a hole for the blasting cap.



4. If castable explosive is used, follow procedure of Wine Bottle Cone Charge, Section II, No. 3, Step 4, a through f.

HOW TO USE:

Method 1. If electrical blasting cap is used:

1. Place blasting cap in hole in top of explosive.

CAUTION: Do not insert blasting cap until charge is ready to be detonated.

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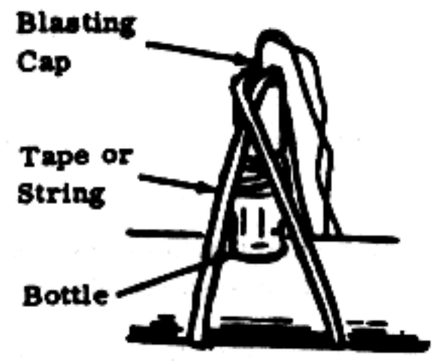
2. Place bottom of Coke Bottle flush against the target. If target is not flat and horizontal, fasten bottle to target by any convenient means, such as by placing tape or string around target and top of bottle. Bottom of bottle acts as stand-off.



CAUTION: Be sure that base of bottle is flush against target and that there is nothing between the target and the base of the bottle.

3. Connect leads from blasting cap to firing circuit.

Method II: If non-electrical blasting cap is used:

1. Crimp cap around fuse.

CAUTION: Be sure fuse is long enough to provide a safe delay.

2. Follow steps 1, 2, and CAUTIONS of Method I.

3. Light fuse when ready to fire.

Section II
33 No. 7

CYLINDRICAL CAVITY SHAPED CHARGE

A shaped charge can be made from common pipe. It will penetrate 1-1/2 in. (3-1/2 cm) of steel, producing a hole 1-1/2 in. (3-1/2 cm) in diameter.

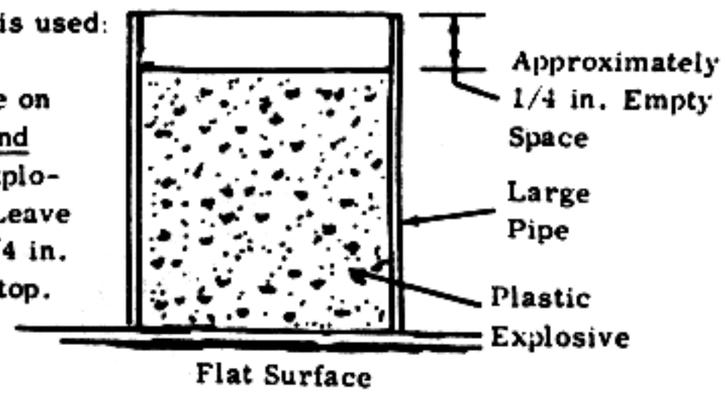
MATERIAL REQUIRED:

Iron or steel pipe, 2 to 2-1/2 in. (5 to 6-1/2 cm) in diameter and 3 to 4 in. (7-1/2 to 10 cm) long
Metal pipe, 1/2 to 3/4 in. (1-1/2 to 2 cm) in diameter and 1-1/2 in. (3-1/2 cm) long, open at both ends. (The wall of the pipe should be as thin as possible.)
Blasting cap
Non-metallic rod, 1/4 in. (6 mm) in diameter
Plastic or castable explosive
2 metal cans of different sizes
Stick or wire } If castable explosive is used
Heat source

PROCEDURE:

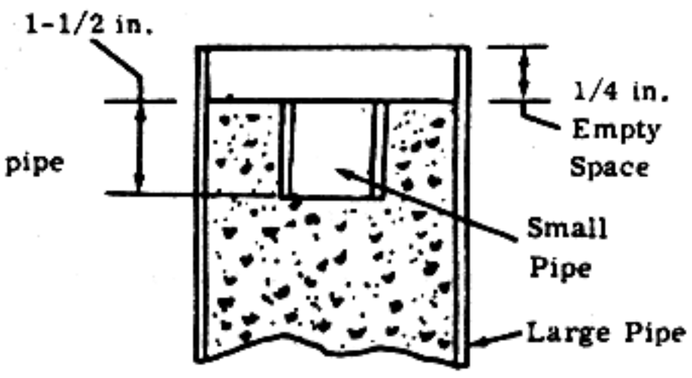
1. If plastic explosive is used:

a. Place larger pipe on flat surface. Hand pack and tamp explosive into pipe. Leave approximately 1/4 in. (6 mm) space at top.



b. Push rod into center of explosive. Enlarge hole in explosive to diameter and length of small pipe.

c. Insert small pipe into hole.



IMPORTANT: Be sure direct contact is made between explosive and small pipe. Tamp explosive around pipe by hand if necessary.

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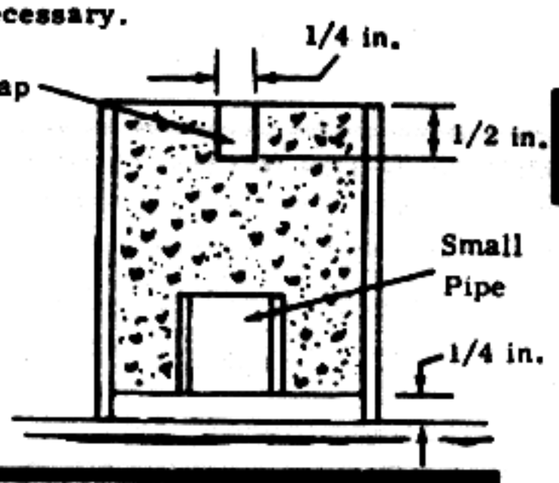
d. Make sure that there is 1/4 in. (6 mm) empty space above small pipe. Remove explosive if necessary.



e. Turn pipe upside down and push rod 1/2 in. (1-1/4 cm) into center of opposite end of explosive to form a hole for the blasting cap.

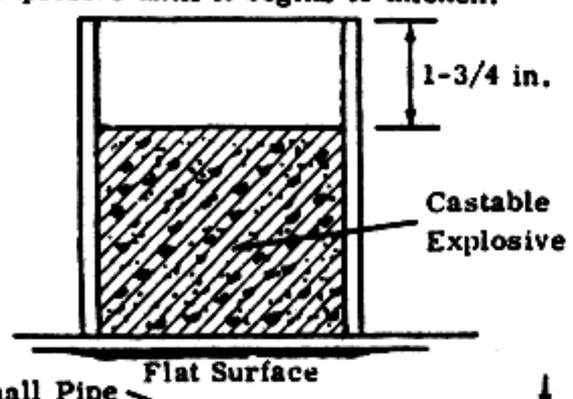
CAUTION: Do not insert blasting cap in hole until ready to fire shaped charge.

2. If TNT or other castable explosive is used:

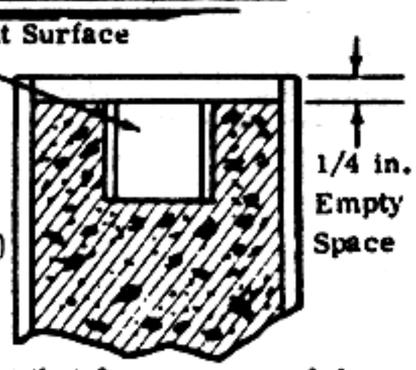
a. Follow procedure, Section II, No. 3, Step 4, Parts a, b, c, including CAUTIONS.

b. When all the explosive has melted, remove the inner container and stir the molten explosive until it begins to thicken.

c. Place large pipe on flat surface. Pour explosive into pipe until it is 1-3/4 in. (4 cm) from the top.



d. Place small pipe in center of large pipe so that it rests on top of explosive. Holding small pipe in place, pour explosive around small pipe until explosive is 1/4 in. (6 mm) from top of large pipe.



e. Allow explosive to cool. Break crust that forms on top of the charge during cooling with a wooden stick and add more explosive. Do this as often as necessary until explosive is 1/4 in. (6 mm) from top.

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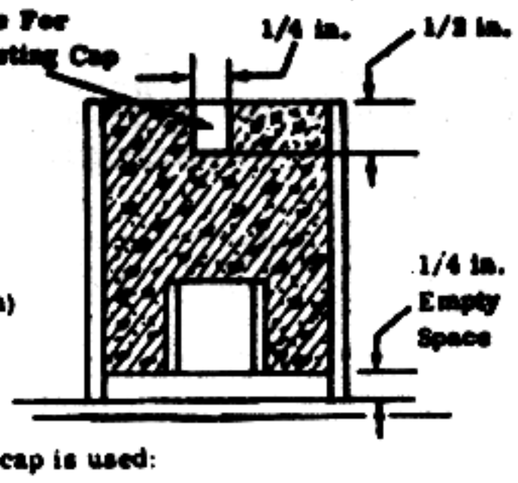
f. When explosive has completely hardened, turn pipe upside down and bore a hole for the blasting cap in the middle of the top of the charge about 1/2 in. (1-1/4 cm) deep.



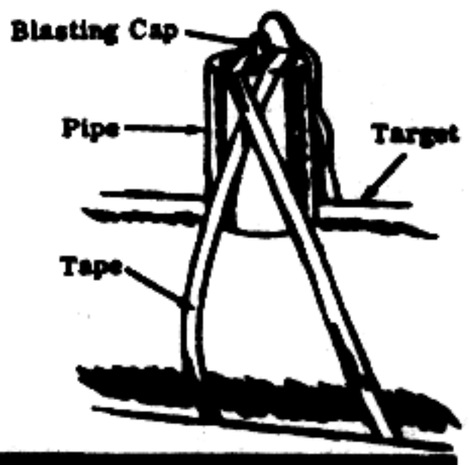
HOW TO USE:

Method I - If electrical blasting cap is used:

1. Place blasting cap in hole made for it.

CAUTION: Do not insert blasting cap until charge is ready to fire.

2. Place other end of pipe flush against the target. Fasten pipe to target by any convenient means, such as by placing tape or string around target and top of pipe, if target is not flat and horizontal.



CAUTION: Be sure that base of pipe is flush against target and that there is nothing between the target and the base of the pipe.

3. Connect leads from blasting cap to firing circuit.

Method II - If non-electrical blasting cap is used:

1. Crimp cap around fuse.

CAUTION: Be sure fuse is long enough to provide a safe delay.

2. Follow Steps 1, 2, and CAUTION of Method I.

3. Light fuse when ready to fire.

Section III

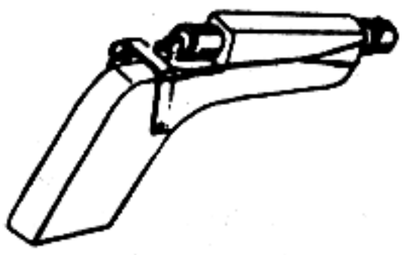
36 No. 1

PIPE PISTOL FOR 9 MM AMMUNITION

A 9 mm pistol can be made from 1/4" steel gas or water pipe and fittings..

MATERIAL REQUIRED

1/4" nominal size steel pipe 4 to 6 inches long with threaded ends.
1/4" Solid pipe plug
Two (2) steel pipe couplings
Metal strap - roughly 1/8" x 1/4" x 5"
Two (2) elastic bands
Flat head nail - 6D or 8D (approx 1/16" diameter)
Two (2) wood screws #8
Wood 8" x 5" x 1"
Drill
1/4" wood or metal rod, (approx 8" long)

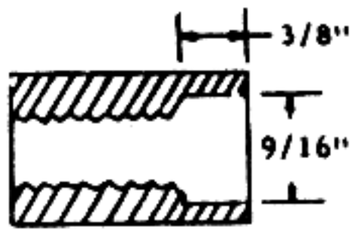


PROCEDURE

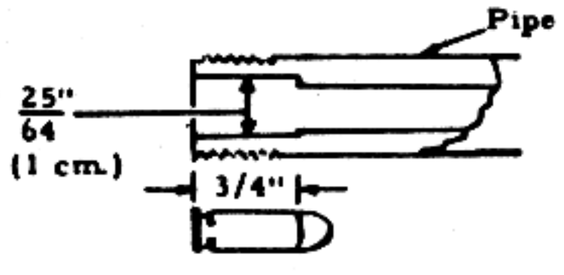
1. Carefully inspect pipe and fittings.
   a. Make sure that there are NO cracks or other flaws in the pipe or fittings.
   b. Check inside diameter of pipe using a 9 mm cartridge as a gauge. The bullet should closely fit into the pipe without forcing but the cartridge case SHOULD NOT fit into pipe.
   c. Outside diameter of pipe MUST NOT BE less than 1 1/2 times bullet diameter (.536 inches; 1.37 cm)

2. Drill a 9/16" (1.43 cm) diameter hole 3/8" (approximately 1 cm) into one coupling to remove the thread.

Drilled section should fit tightly over smooth section of pipe.



3. Drill a 25/64" (1 cm) diameter hole 3/4" (1.9 cm) into pipe. Use cartridge as a gauge; when a cartridge is inserted into the pipe, the base of the case should be even with the end of the pipe. Thread coupling tightly onto pipe, drilled end first.



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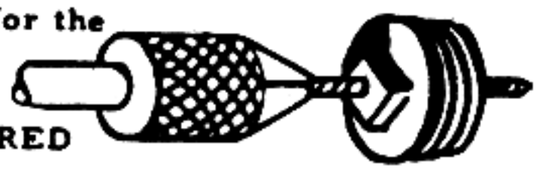
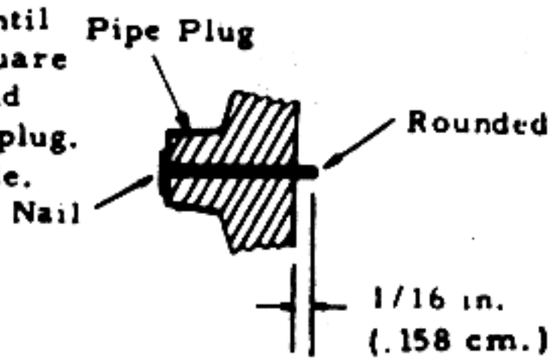
4. Drill a hole in the center of the pipe plug just large enough for the nail to fit through.

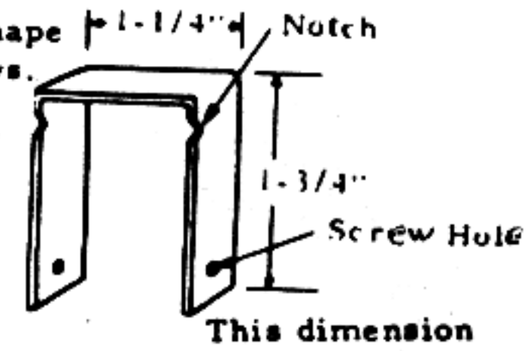


HOLE MUST BE CENTERED IN PLUG.

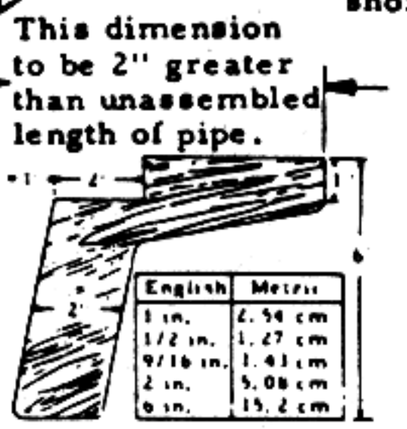
5. Push nail through plug until head of nail is flush with square end. Cut nail off at other end 1/16" (.158 cm) away from plug. Round off end of nail with file.



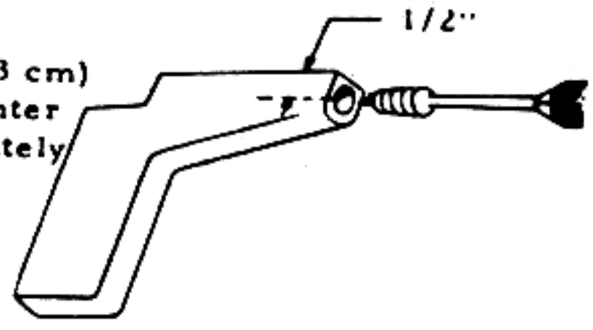
6. Bend metal strap to "U" shape and drill holes for wood screws. File two small notches at top.



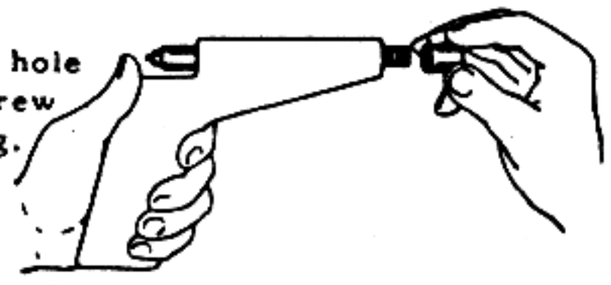
7. Saw or otherwise shape 1" (2.54 cm) thick hard wood into stock.



8. Drill a 9/16" diameter (1.43 cm) hole through the stock. The center of the hole should be approximately 1/2" (1.27 cm) from the top.



9. Slide the pipe through this hole and attach front coupling. Screw drilled plug into rear coupling.



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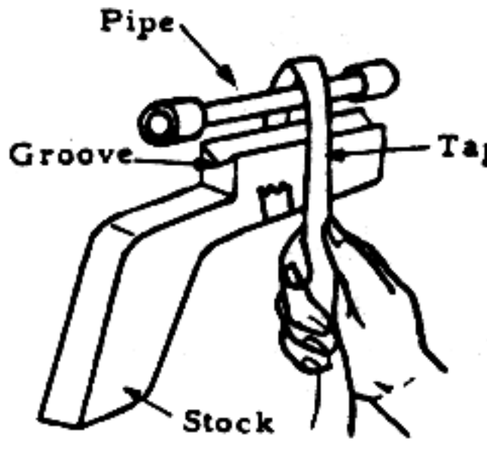
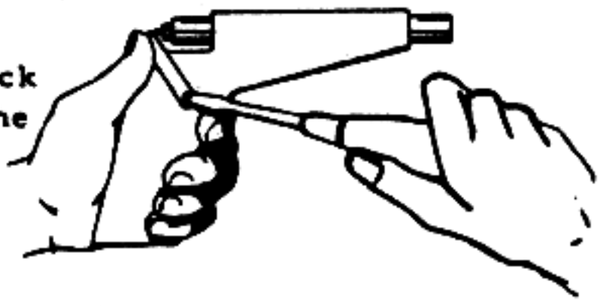
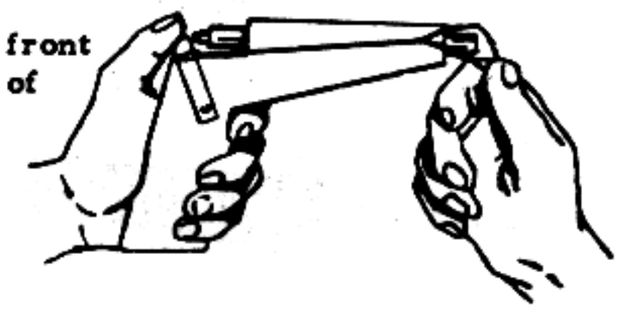


NOTE: If 9/16" drill is not available cut a "V" groove in the top of the stock and tape pipe securely in place.

10. Position metal strap on stock so that top will hit the head of the nail. Attach to stock with wood screw on each side.



11. String elastic bands from front coupling to notch on each side of the strap.



SAFETY CHECK - TEST FIRE PISTOL BEFORE HAND FIRING

1. Locate a barrier such as a stone wall or large tree which you can stand behind in case the pistol ruptures when fired.

2. Mount pistol solidly to a table or other rigid support at least ten feet in front of the barrier.

3. Attach a cord to the firing strap on the pistol.

4. Holding the other end of the cord, go behind the barrier.

5. Pull the cord so that the firing strap is held back.

6. Release the cord to fire the pistol. (If pistol does not fire, shorten the elastic bands or increase their number.)

IMPORTANT: Fire at least five rounds from behind the barrier and then re-inspect the pistol before you attempt to hand fire it.

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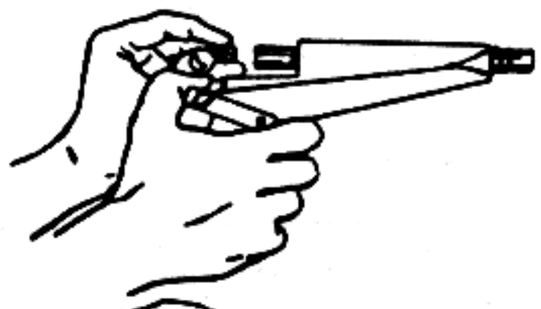
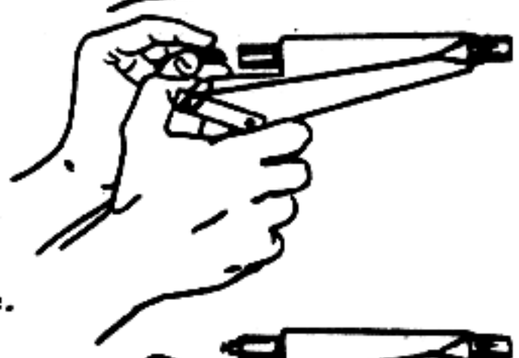
HOW TO OPERATE PISTOL

1. To Load



a. Remove plug from rear coupling.



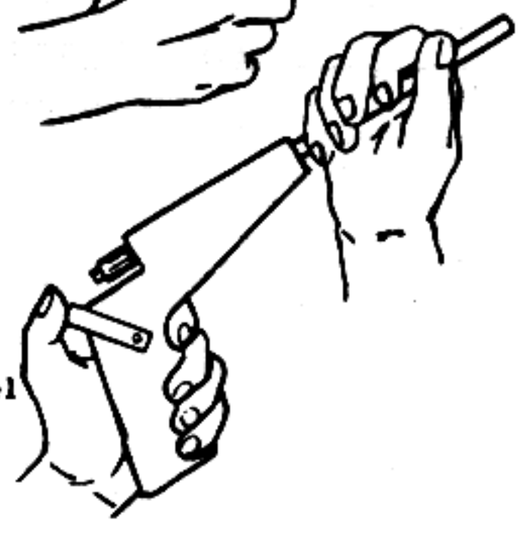
b. Place cartridge into pipe.

c. Replace plug.

2. To Fire

a. Pull strap back and hold with thumb until ready.

b. Release strap.



3. To Remove Shell Case

a. Remove plug from rear coupling.

b. Insert 1/4" diameter steel or wooden rod into front of pistol and push shell case out.

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SHOTGUN (12 GAUGE)

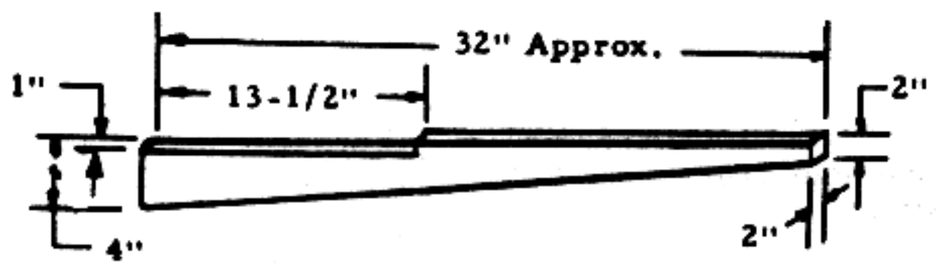
A 12-gauge shotgun can be made from 3/4" water or gas pipe and fittings.

MATERIALS REQUIRED

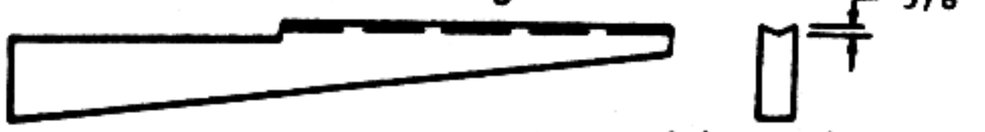
Wood 2" x 4" x 32"
3/4" nominal size water or gas pipe 20" to 30" long threaded on one end.
3/4" steel coupling
Solid 3/4" pipe plug
Metal strap (1/4" x 1/16" x 4")
Twine, heavy (100 yards approximately)
3 wood screws and screwdriver
Flat head nail 6D or 8D
Hand drill
Saw or knife
File
Shellac or lacquer
Elastic Bands

PROCEDURE

1. **Carefully inspect pipe and fittings.**
   a. **Make sure that there are no cracks or other flaws.**
   b. **Check inside diameter of pipe. A 12-gauge shot shell should fit into the pipe but the brass rim should not fit.**
   c. **Outside diameter of pipe must be at least 1 in. (2.54 cm).**



2. **Cut stock from wood using a saw or knife.**



3. **Cut a 3/8" deep "V" groove in top of the stock.**

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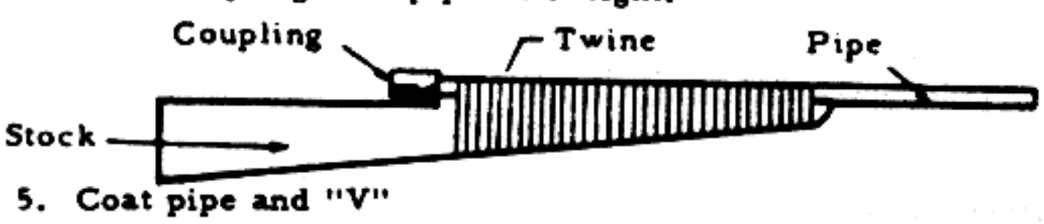
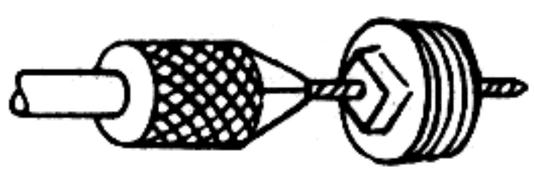
4. **Turn coupling onto pipe until tight.**

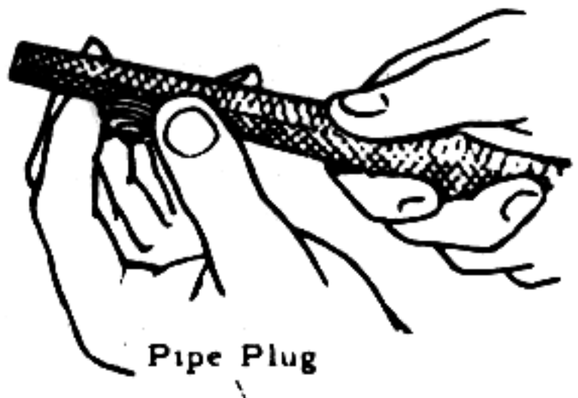


5. **Coat pipe and "V" groove of stock with shellac or lacquer and, while still wet, place pipe in "V" groove and wrap pipe and stock together using two heavy layers of twine. Coat twine with shellac or lacquer after each layer.**

6. **Drill a hole through center of pipe plug large enough for nail to pass through.**



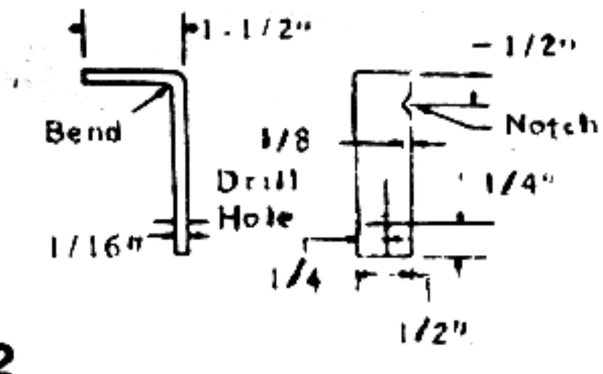
7. **File threaded end of plug flat.**



8. **Push nail through plug and cut off flat 1/32" past the plug.**

9. **Screw plug into coupling.**

10. **Bend 4" metal strap into "L" shape and drill hole for wood screw. Notch metal strap on the long side 1/2" from bend.**



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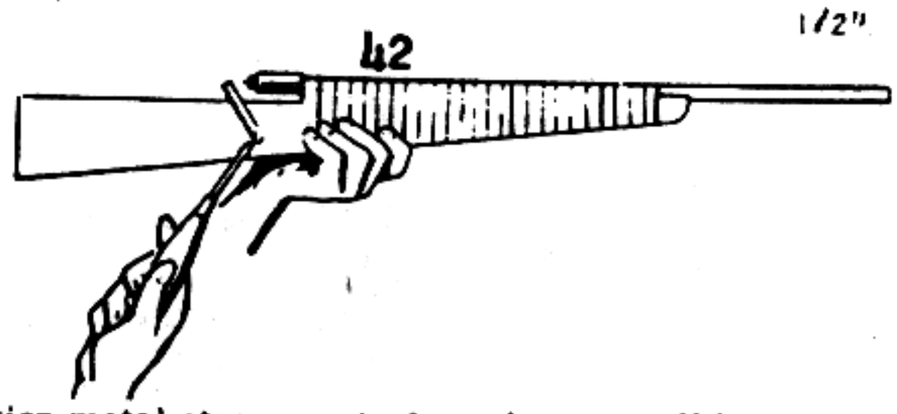
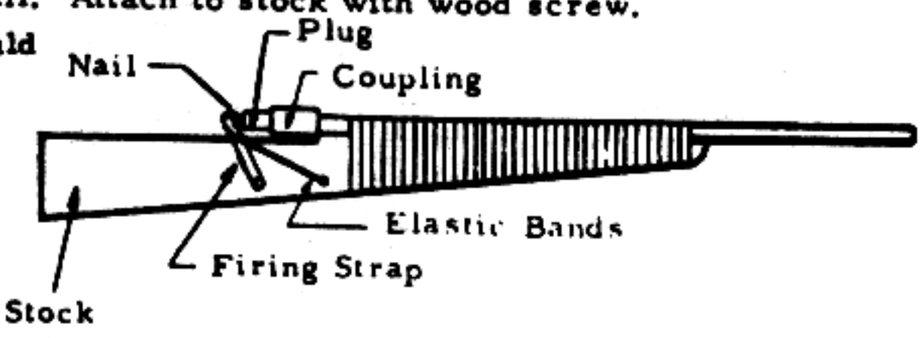


11. **Position metal strap on stock so that top will hit the head of the nail. Attach to stock with wood screw.**



12. **Place screw in each side of stock about 4" in front of metal strap. Pass elastic bands through notch in metal strap and attach to screw on each side of the stock.**

SAFETY CHECK - TEST FIRE SHOTGUN BEFORE HAND FIRING

1. **Locate a barrier such as a stone wall or large tree which you can stand behind in case the weapon explodes when fired.**

2. **Mount shotgun solidly to a table or other rigid support at least ten feet in front of the barrier.**

3. **Attach a long cord to the firing strap on the shotgun.**

4. **Holding the other end of the cord, go behind the barrier.**

5. **Pull the cord so that the firing strap is held back.**

6. **Release the cord to fire the shotgun. (If shotgun does not fire, shorten the elastic bands or increase their number.)**

IMPORTANT: Fire at least five rounds from behind the barrier and then re-inspect the shotgun before you attempt to shoulder fire it.

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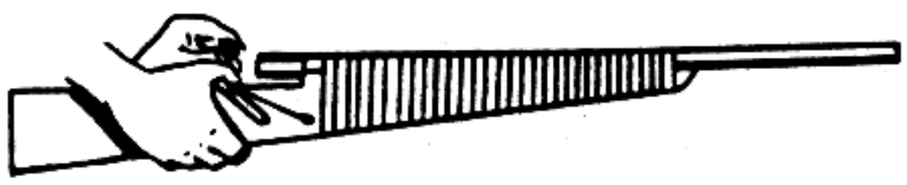
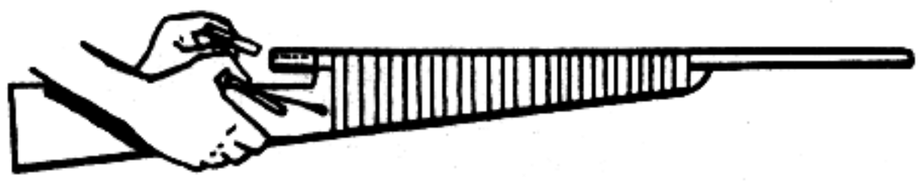
HOW TO OPERATE SHOTGUN

1. To Load



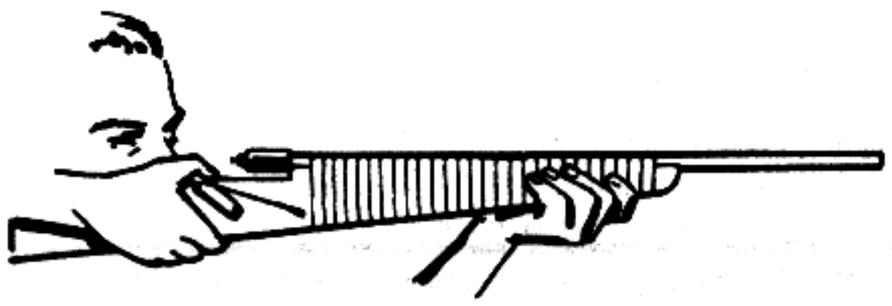
a. Take plug out of coupling.



b. Put shotgun shell into pipe.

c. Screw plug hand-tight into coupling.

2. To Fire



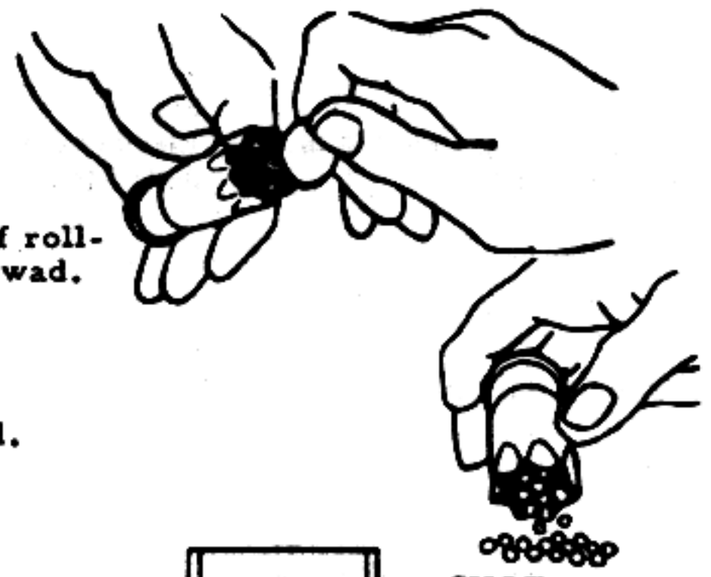
a. Pull strap back and hold with thumb.

b. Release strap.

3. To Unload Gun

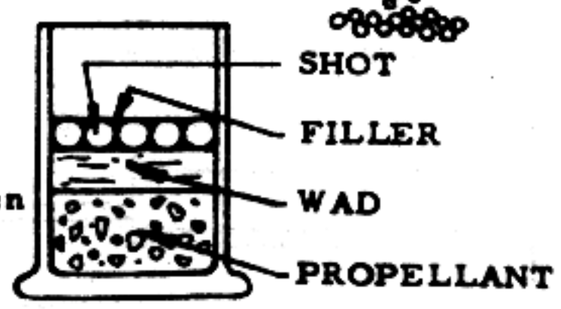
a. Take plug out of coupling.

b. Shake out used cartridge.



NOTE: If cartridge is of roll-crimp type, remove top wad.

2. Pour shot from shell.



3. Replace one layer of shot in the cartridge. Pour in filler material to fill the spaces between the shot.

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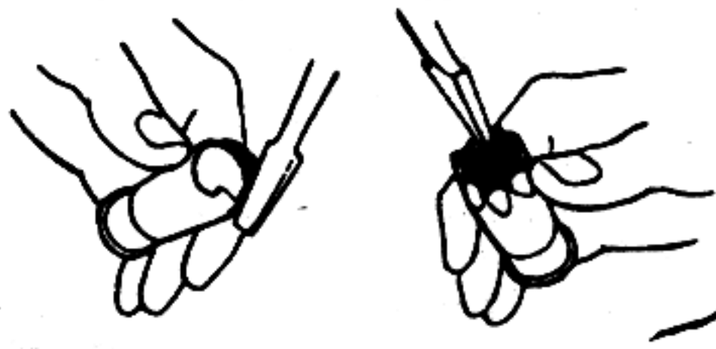
4. Repeat Step 3 until all shot has been replaced.

5. Replace top wad (if applicable) and re-fold crimp.



6. Roll shell on flat surface to smooth out crimp and restore roundness.

7. Seal end of case with wax.

Section III
44 No. 3
SHOTSHELL DISPERSION CONTROL

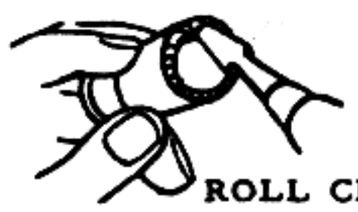
When desired, shotshell can be modified to reduce shot dispersion.

MATERIAL REQUIRED:

Shotshell
Screwdriver or knife
Any of the following filler materials:
- Crushed Rice
- Rice Flour
- Dry Bread Crumbs
- Fine Dry Sawdust

PROCEDURE:

1. Carefully remove crimp from shotshell using a screwdriver or knife.

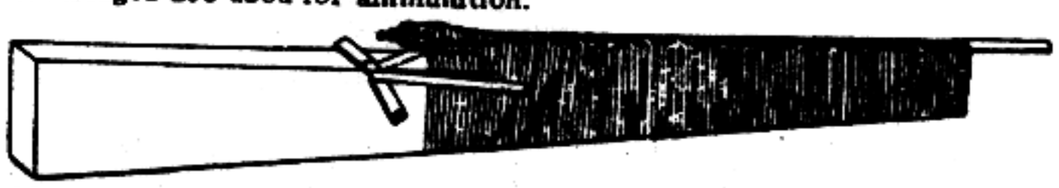


HOW TO USE:

This round is loaded and fired in the same manner as standard shotshell. The shot spread will be about 2/3 that of a standard round.

Section III
46 No. 4
CARBINE (7.62 mm Standard Rifle Ammunition)

A rifle can be made from water or gas pipe and fittings. Standard cartridges are used for ammunition.



MATERIAL REQUIRED:

Wood approximately 2 in. x 4 in. x 30 in.
1/4 in. nominal size iron water or gas pipe 20 in. long threaded at one end.
Twine, heavy (100 yards approx.)
3 wood screws and screwdriver
Flat head nail about 1 in. long
Hand drill
Saw or knife

3/8 in. to 1/4 in. reducer
3/8 in. x 1-1/2 in. threaded pipe
3/8 in. pipe coupling
Metal strap approximately 1/2 in. x 1/16 in. x 4 in.
File
Pipe wrench
Shellac or lacquer
Elastic bands
Solid 3/8 in. pipe plug

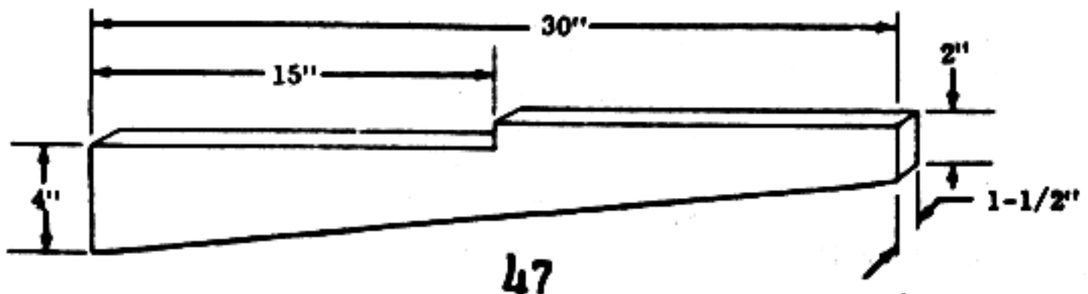
PROCEDURE:

1. Inspect pipe and fittings carefully.

   a. Be sure that there are no cracks or flaws.

   b. Check inside diameter of pipe. A 7.62 mm projectile should fit into 3/8 in. pipe.

2. Cut stock from wood using saw or knife.



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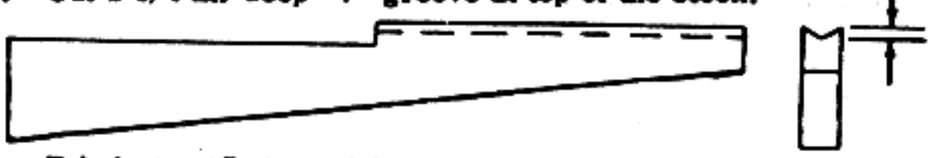
3. Cut a 1/4 in. deep "V" groove in top of the stock.



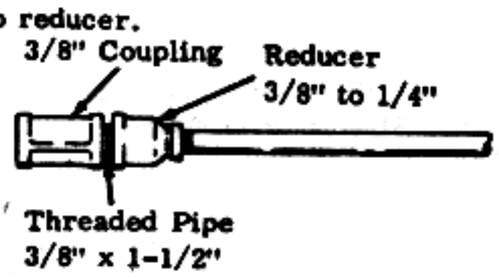
4. Fabricate rifle barrel from pipe.

   a. File or drill inside diameter of threaded end of 20 in. pipe for about 1/4 in. so neck of cartridge case will fit in.

   b. Screw reducer onto threaded pipe using pipe wrench.

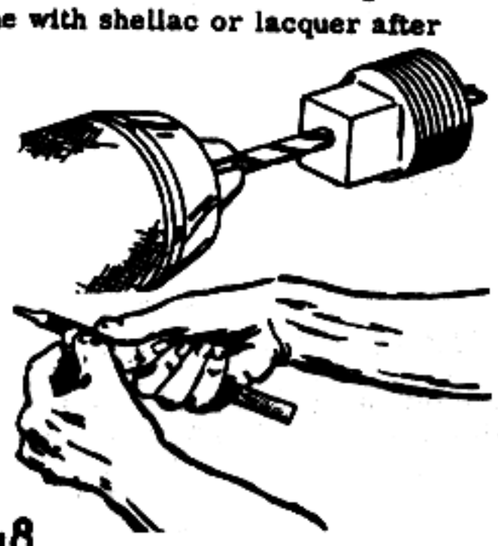
   c. Screw short threaded pipe into reducer.

   d. Turn 3/8 pipe coupling onto threaded pipe using pipe wrench. All fittings should be as tight as possible. Do not split fittings.



5. Coat pipe and "V" groove of stock with shellac or lacquer. While still wet, place pipe in "V" groove and wrap pipe and stock together using two layers of twine. Coat twine with shellac or lacquer after each layer.

6. Drill a hole through center of pipe plug large enough for nail to pass through.



7. File threaded end of plug flat.

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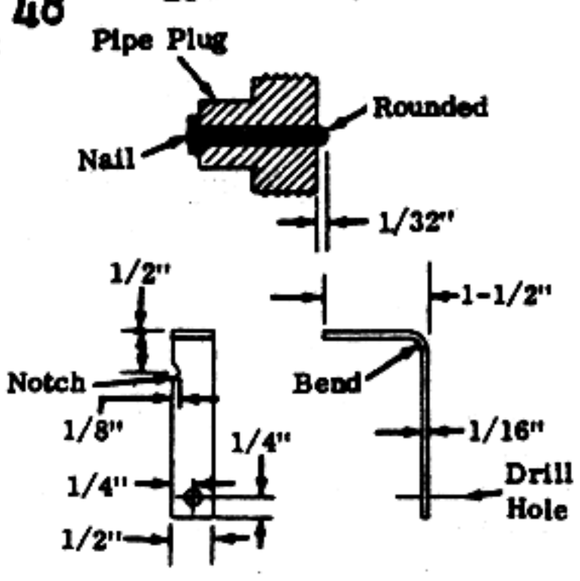
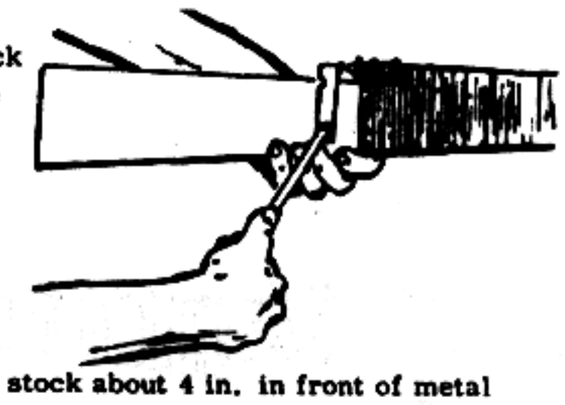
8. Push nail through plug and cut off rounded 1/32 in. (2 mm) past the plug.

9. Screw plug into coupling.

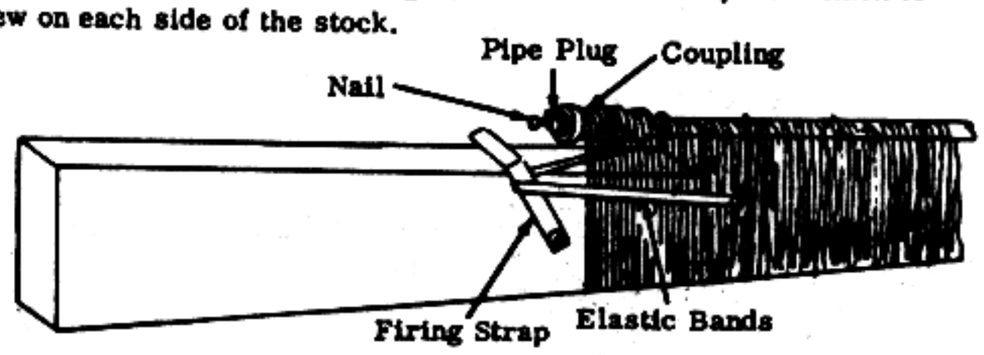
10. Bend 4 in. metal strap into "L" shape and drill hole for wood screw. Notch metal strap on the long side 1/2 in. from bend.



11. Position metal strap on stock so that top will hit the head of the nail. Attach to stock with wood screw.



12. Place screw in each side of stock about 4 in. in front of metal strap. Pass elastic bands through notch in metal strap and attach to screw on each side of the stock.



SAFETY CHECK - TEST FIRE RIFLE BEFORE HAND FIRING

1. Locate a barrier such as a stone wall or large tree which you can stand behind to test fire weapon.

2. Mount rifle solidly to a table or other rigid support at least ten feet in front of the barrier.

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3. Attach a long cord to the firing strap on the rifle.

4. Holding the other end of the cord, go behind the barrier.

5. Pull the cord so that the firing strap is held back.

6. Release the cord to fire the rifle. (If the rifle does not fire, shorten the elastic bands or increase their number.)

IMPORTANT: Fire at least five rounds from behind a barrier and then reinspect the rifle before you attempt to shoulder fire it.

HOW TO OPERATE RIFLE:

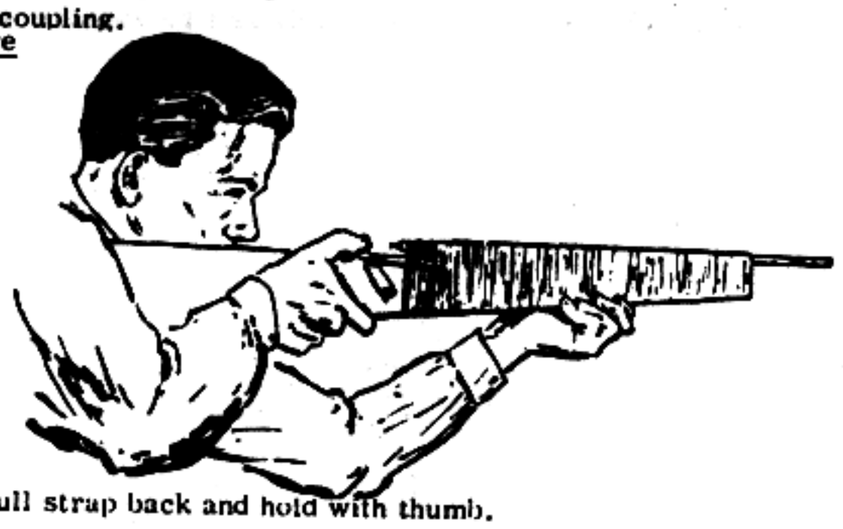
1. To Load

   a. Remove plug from coupling.

   b. Put cartridge into pipe.

   c. Screw plug hand-tight into coupling.

2. To Fire



   a. Pull strap back and hold with thumb.

   b. Release strap.

3. To Unload Gun

   a. Take plug out of coupling.

   b. Drive out used case using stick or twig.

50 Section III
No. 5

REUSABLE PRIMER

A method of making a previously fired primer reusable.

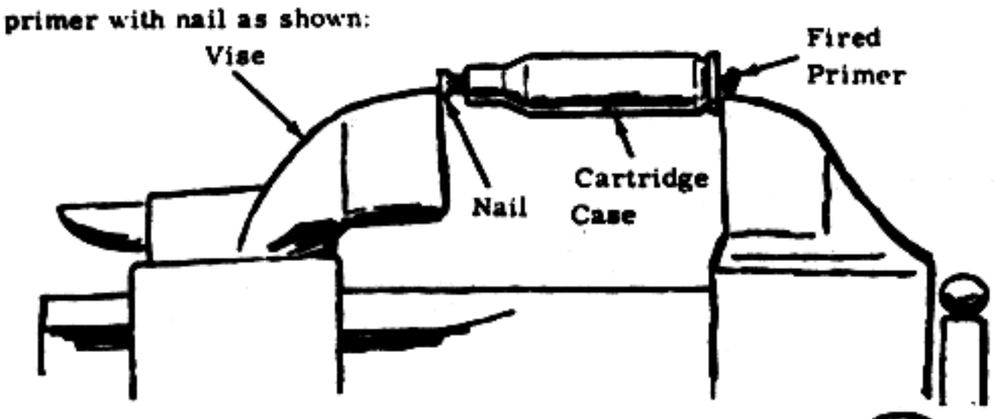
MATERIAL REQUIRED:

Used cartridge case
2 long nails having approximately the same diameter as the inside of the primer pocket
"Strike-anywhere" matches - 2 or 3 are needed for each primer
Vise
Hammer
Knife or other sharp edged instrument

PROCEDURE:

1. File one nail to a needle point so that it is small enough to fit through hole in primer pocket.

2. Place cartridge case and nail between jaws of vise. Force out fired primer with nail as shown:



3. Remove anvil from primer cup.

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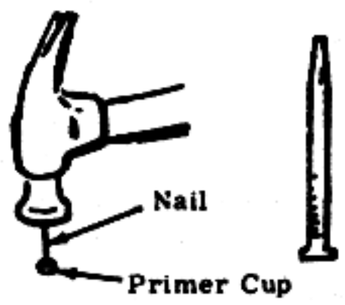
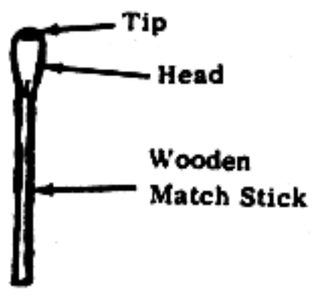
4. File down point of second nail until tip is flat.

5. Remove indentations from face of primer cup with hammer and flattened nail.

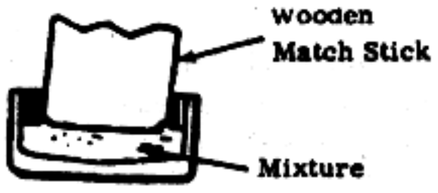


6. Cut off tips of the heads of "strike-anywhere" matches using knife. Carefully crush the match tips on dry surface with wooden match stick until the mixture is the consistency of sugar.

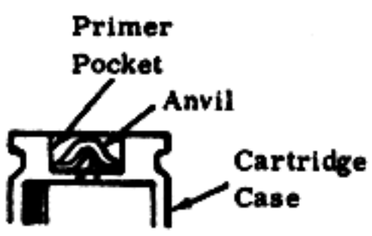


CAUTION: Do not crush more than 3 match tips at one time or the mixture may explode.

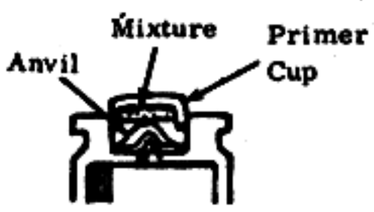
7. Pour mixture into primer cup. Compress mixture with wooden match stick until primer cup is fully packed.



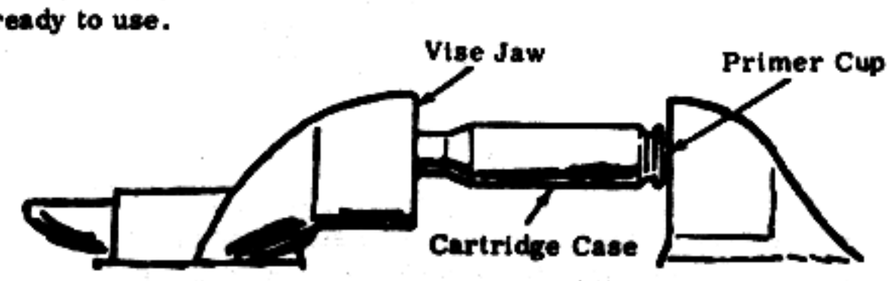
8. Place anvil in primer pocket with legs down.



9. Place cup in pocket with mixture facing downward.



10. Place cartridge case and primer cup between vise jaws, and press slowly until primer is seated into bottom of pocket. The primer is now ready to use.



52 Section III
No. 6

PIPE PISTOL FOR .45 CALIBER AMMUNITION

A .45 caliber pistol can be made from 3/8 in. nominal diameter steel gas or water pipe and fittings. Lethal range is about 15 yards (13-1/2 meters).

MATERIAL REQUIRED:

Steel pipe, 3/8 in. (1 cm) nominal diameter and 6 in. (15 cm) long with threaded ends.
2 threaded couplings to fit pipe
Solid pipe plug to fit pipe coupling
Hard wood, 8-1/2 in. x 6-1/2 in. x 1 in. (21 cm x 16-1/2 cm x 2-1/2 cm)
Tape or string
Flat head nail, approximately 1/16 in. (1-1/2 mm) in diameter
2 wood screws, approximately 1/16 in. (1-1/2 mm) in diameter
Metal strap, 5 in. x 1/4 in. x 1/8 in. (12-1/2 cm x 6 mm x 1 mm)
Bolt, 4 in. (10 cm) long, with nut (optional).
Elastic bands
Drills, one 1/16 in. (1-1/2 mm) in diameter, and one having same diameter as bolt (optional).
Rod, 1/4 in. (6mm) in diameter and 8 in. (20 cm) long
Saw or knife

PROCEDURE:

1. Carefully inspect pipe and fittings.

   a. Make sure that there are no cracks or other flaws in the pipe and fittings.

   b. Check inside diameter of pipe using a .45 caliber cartridge as a gauge. The cartridge case should fit into the pipe snugly but without forcing.

   c. Outside diameter of pipe MUST NOT BE less than 1-1/2 times the bullet diameter.

2. Follow procedure of Section III, No. 1, steps 4, 5, and 6.

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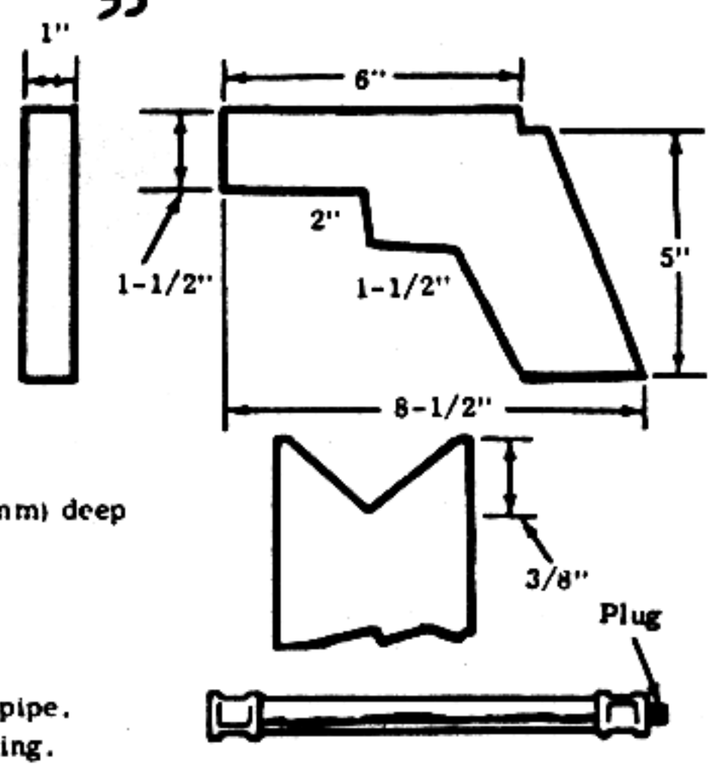
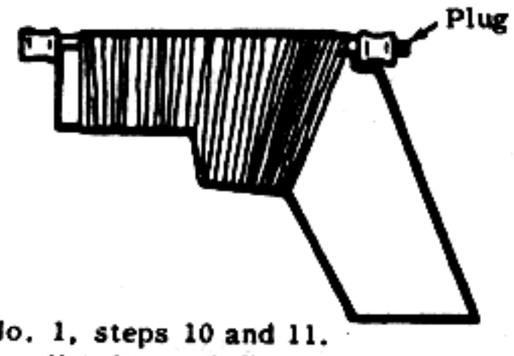
3. Cut stock from wood using saw or knife.

Inches	Centimeters
1-1/2	4 cm
8-1/2	26-1/2
6	20
1-1/2	4
5	12-1/2



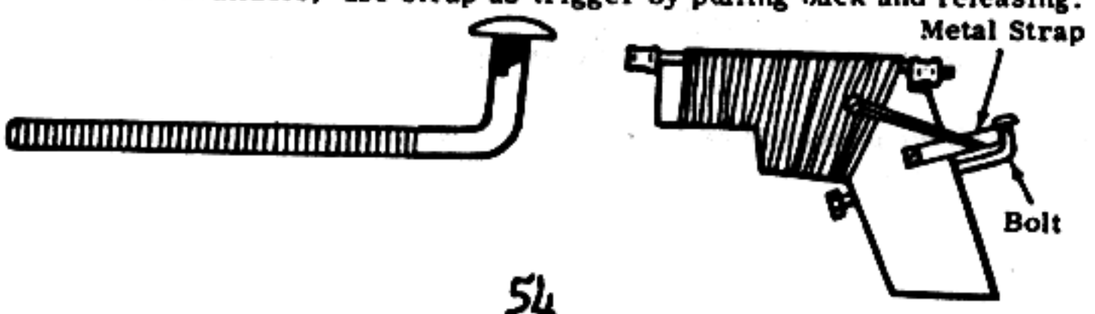
4. Cut a 3/8 in. (9-1/2 mm) deep groove in top of stock.

5. Screw couplings onto pipe. Screw plug into one coupling.



6. Securely attach pipe to stock using string or tape.

7. Follow procedures of Section III, No. 1, steps 10 and 11.
8. (Optional) Bend bolt for trigger. Drill hole in stock and place bolt in hole so strap will be anchored by bolt when pulled back. If bolt is not available, use strap as trigger by pulling back and releasing.



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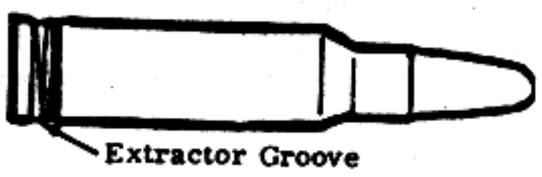
9. Follow SAFETY CHECK, Section III, No. 1

HOW TO USE:

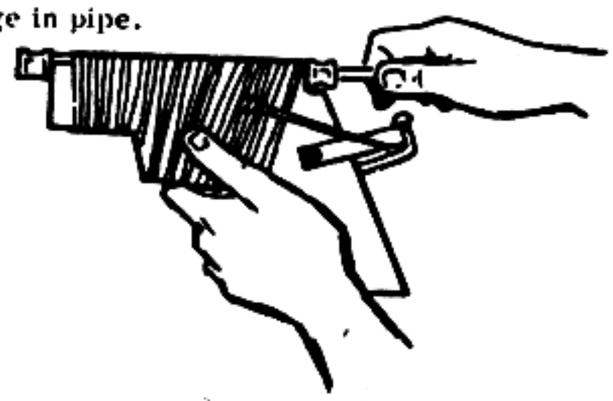
1. To load:

   a. Remove plug from rear coupling.

   b. Wrap string or elastic band around extractor groove so case will seat into barrel securely.



   c. Place cartridge in pipe.

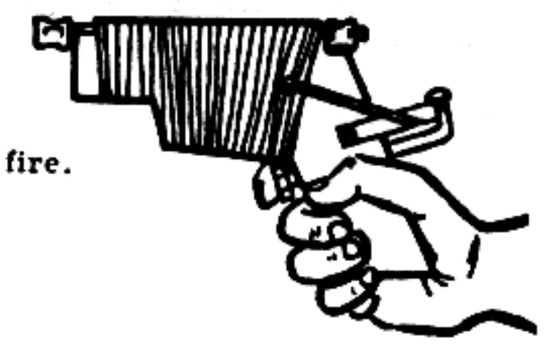


   d. Replace plug.

2. To Fire:

   a. Pull metal strap back and anchor in trigger.

   b. Pull trigger when ready to fire.

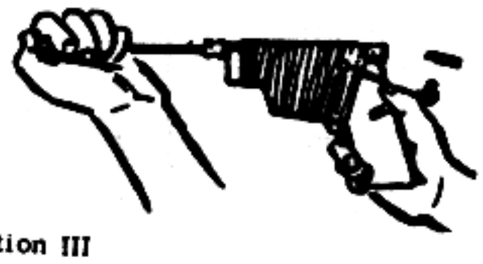


NOTE: If bolt is not used, pull strap back and release.

3. To remove cartridge case:

   a. Remove plug from rear coupling.

   b. Insert rod into front of pistol and push cartridge case out.



55 Section III No. 7

MATCH GUN

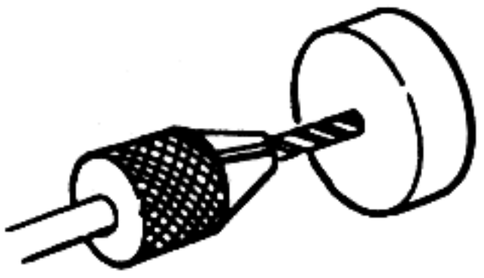
An improvised weapon using safety match heads as the propellant and a metal object as the projectile. Lethal range is about 40 yards (36 meters).

MATERIAL REQUIRED:

Metal pipe 24 in. (61 cm) long and 3/8 in. (1 cm) in diameter (nominal size) or its equivalent, threaded on one end.
End cap to fit pipe
Safety matches - 3 books of 20 matches each.
Wood - 28 in. x 4 in. x 1 in. (70 cm x 10 cm x 2.5 cm)
Toy caps OR safety fuse OR "Strike-anywhere matches" (2)
Electrical tape or string
Metal strap, about 4 in. x 1/4 in. x 3/16 in. (10 cm x 6 mm x 4.5 mm)
2 rags, about 1 in x 12 in. and 1 in. x 3 in. (2-1/2 cm x 30 cm and 2-1/2 cm x 8 cm)
Wood screws
Elastic bands
Metal object (steel rod, bolt with head cut off, etc.), approximately 7/16 in. (11 mm) in diameter, and 7/16 in. (11 mm) long if iron or steel, 1-1/4 in. (31 mm) long if aluminum, 5/16 in. (8mm) long if lead.
Metal disk 1 in. (2-1/2 cm) in diameter and 1/16 in. (1-1/2 mm) thick
Bolt, 3/32 in. (2-1/2 mm) or smaller in diameter and nut to fit
Saw or knife

PROCEDURE:

1. Carefully inspect pipe and fittings. Be sure that there are no cracks or other flaws.



2. Drill small hole in center of end cap. If safety fuse is used, be sure it will pass through this hole.

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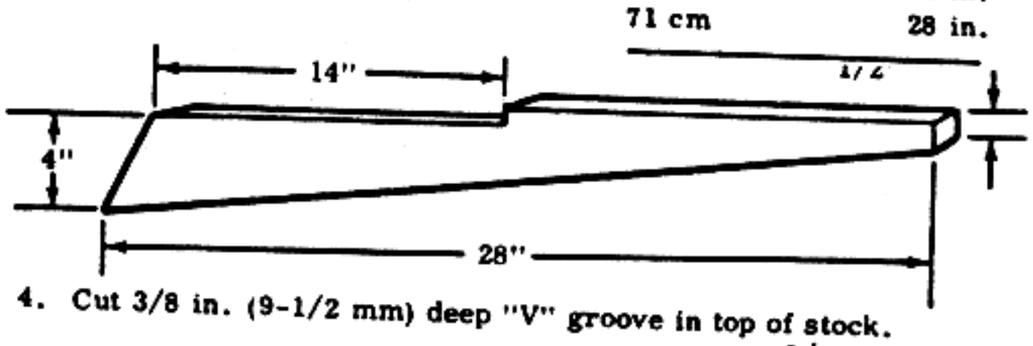
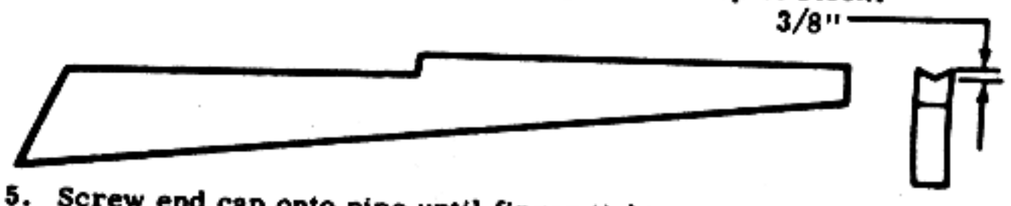
Metric	English
5 cm	2 in.
10 cm	4 in.
36 cm	14 in.
71 cm	28 in.

3. Cut stock from wood using saw or knife.

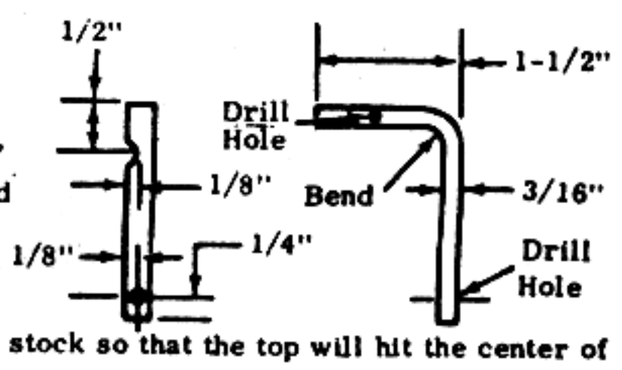


4. Cut 3/8 in. (9-1/2 mm) deep "V" groove in top of stock.



5. Screw end cap onto pipe until finger tight.

6. Attach pipe to stock with string or tape.



7. Bend metal strap into "L" shape and drill holes for wood screw. Notch metal strap on long side 1/2 in. (1 cm) from bend.

8. Position metal strap on stock so that the top will hit the center of hole drilled in end cap.

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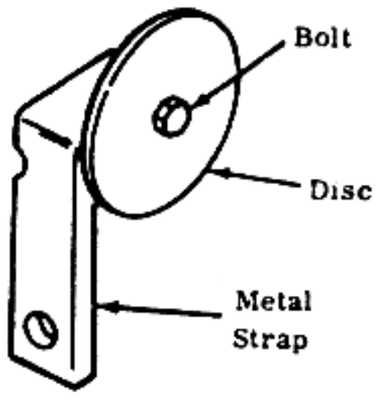
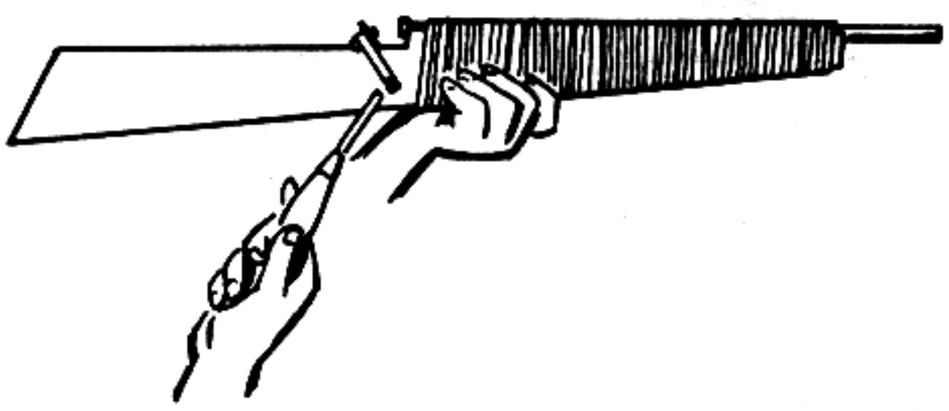
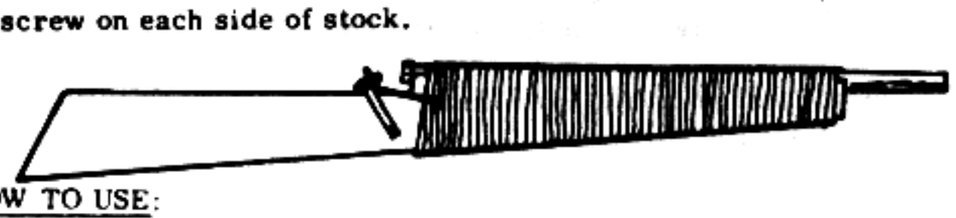


9. Attach metal disk to strap with nut and bolt. This will deflect blast from hole in end cap when gun is fired. Be sure that head of bolt is centered on hole in end cap.

10. Attach strap to stock with wood screws.



11. Place screw on each side of stock about 4 in. (10 cm) in front of metal strap. Pass elastic bands through notch in metal strap and attach to screw on each side of stock.



HOW TO USE:

A. When Toy Caps Are Available:

1. Cut off match heads from 3 books of matches with knife. Pour match heads into pipe.

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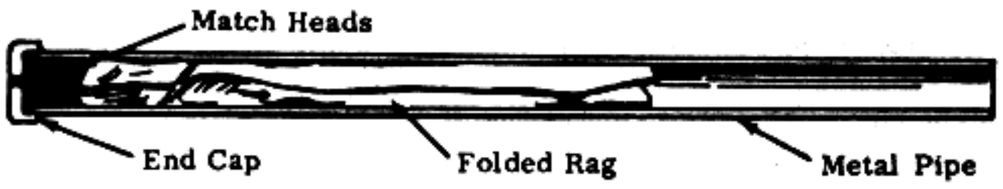
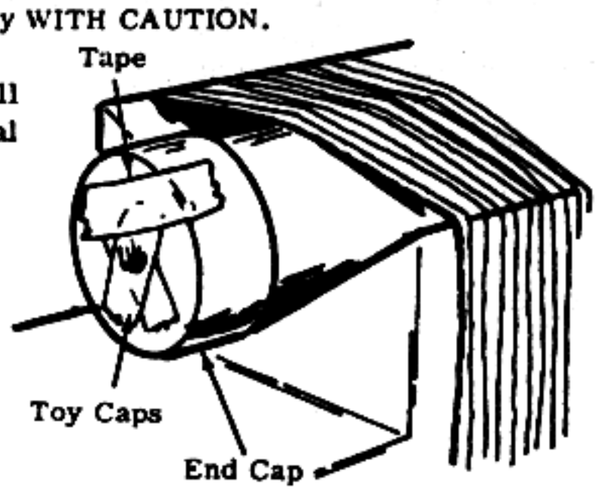
2. Fold one end of 1 in. x 12 in. rag 3 times so that it becomes a one inch square of 3 thicknesses. Place rag into pipe to cover match heads, folded end first. Tamp firmly WITH CAUTION.



3. Place metal object into pipe. Place 1 in. x 3 in. rag into pipe to cover projectile. Tamp firmly WITH CAUTION.

4. Place 2 toy caps over small hole in end cap. Be sure metal strap will hit caps when it is released.

NOTE: It may be necessary to tape toy caps to end cap.



5. When ready to fire, pull metal strap back and release.

B. When "Strike-Anywhere" Matches Are Available:

1. Follow steps 1 through 3 in A.

2. Carefully cut off tips of heads of 2 "strike-anywhere" matches with knife.

3. Place one tip in hole in end cap. Push in with wooden end of match stick.

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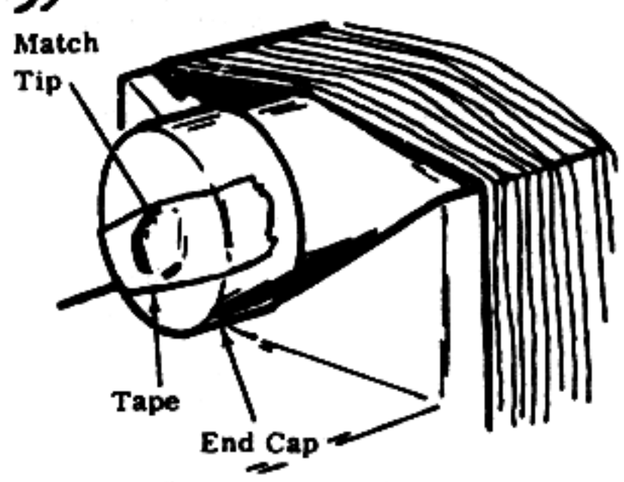
4. Place second match tip on a piece of tape. Place tape so match tip is directly over hole in end cap.



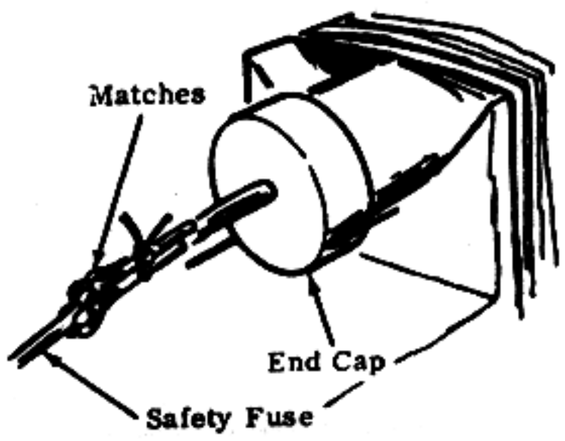
5. When ready to fire, pull metal strap back and release.

C. When Safety Fuse Is Available: (Recommended for Booby Traps)

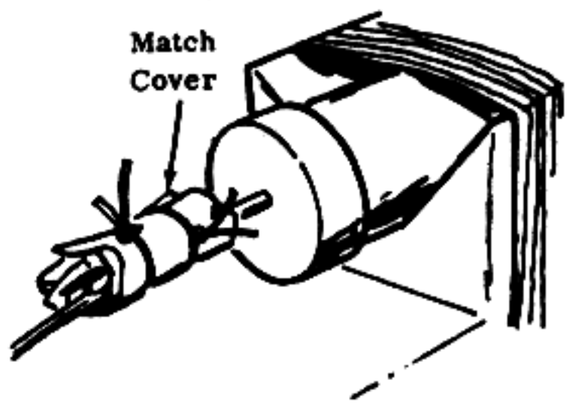
1. Remove end cap from pipe. Knot one end of safety fuse. Thread safety fuse through hole in end cap so that knot is on inside of end cap.

2. Follow steps 1 through 3 in A.

3. Tie several matches to safety fuse near outside of end cap.
NOTE: Bare end of safety fuse should be inside match head cluster.



4. Wrap match covers around matches and tie. Striker should be in contact with match bands.



5. Replace end cap on pipe.

6. When ready to fire, pull match cover off with strong, firm, quick motion.

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SAFETY CHECK - TEST FIRE GUN BEFORE HAND FIRING

1. Locate a barrier such as a stone wall or large tree which you can stand behind in case the weapon explodes when fired.

2. Mount gun solidly to a table or other rigid support at least ten feet in front of the barrier.

3. Attach a long cord to the firing strap on the gun.

4. Holding the other end of the cord, go behind the barrier.

5. Pull the cord so that the firing strap is held back.

6. Release the cord to fire the gun. (If gun does not fire, shorten the elastic bands or increase their number.)

IMPORTANT: Fire at least five rounds from behind the barrier and then re-inspect the gun before you attempt to shoulder fire it.

Section III
61 No. 8
RIFLE CARTRIDGE

NOTE: See Section III, No. 5 for reusable primer.

A method of making a previously fired rifle cartridge reusable.

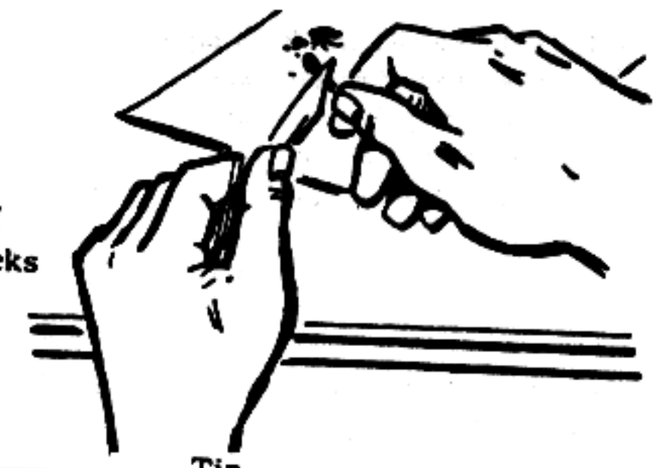
MATERIAL REQUIRED:

Empty rifle cartridge, be sure that it still fits inside gun.
Threaded bolt that fits into neck of cartridge at least 1-1/4 in. (3 cm) long.
Safety or "strike-anywhere" matches (about 58 matches are needed for 7.62 mm cartridge)
Rag wad (about 3/4 in. (1-1/2 cm) square for 7.62 mm cartridge)
Knife
Saw

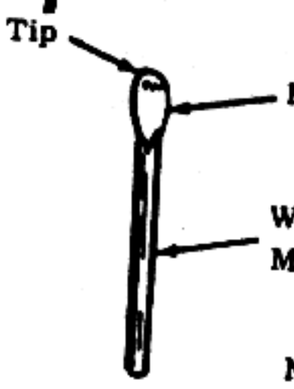
NOTE: Number of matches and size of rag wad depend on particular cartridge used.

PROCEDURE:

1. Remove coating on heads of matches by scraping match sticks with sharp edge.



CAUTION: If wooden "strike-anywhere" matches are used, cut off tips first. Discard tips or use for Reusable Primer, Section III, No. 5.



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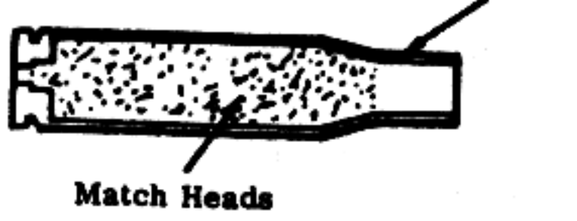
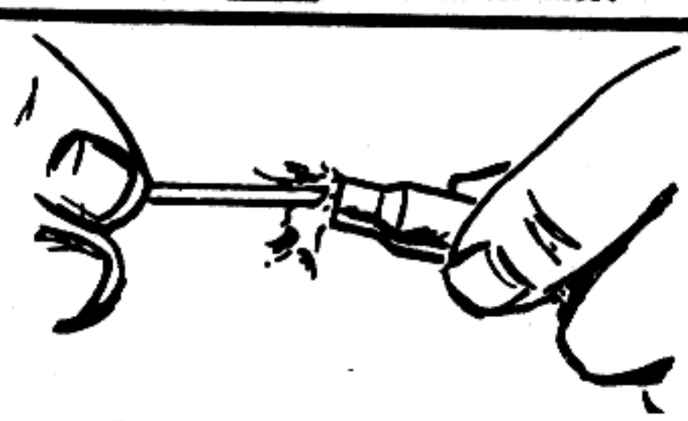
2. Fill previously primed cartridge case with match head coatings up to its neck. Pack evenly and tightly with match stick.

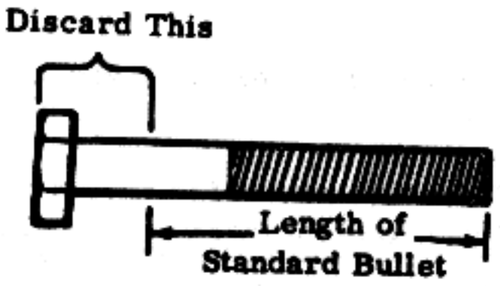


CAUTION: Remove head of match stick before packing. In all packing operations, stand off to the side and pack gently. Do not hammer.

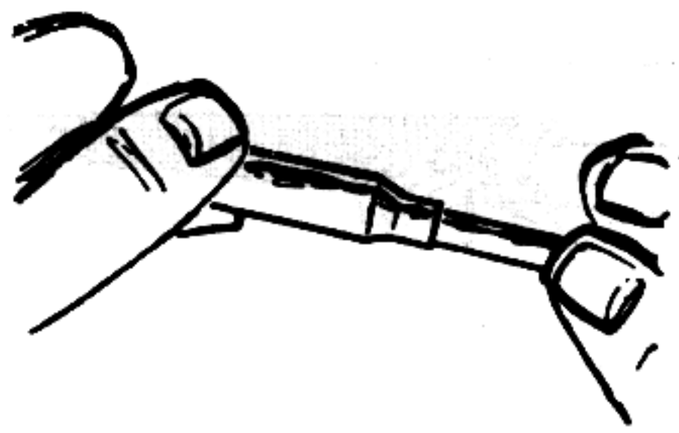
3. Place rag wad in neck of case. Pack with match stick from which head was removed.



4. Saw off head end of bolt so remainder is approximately the length of the standard bullet.



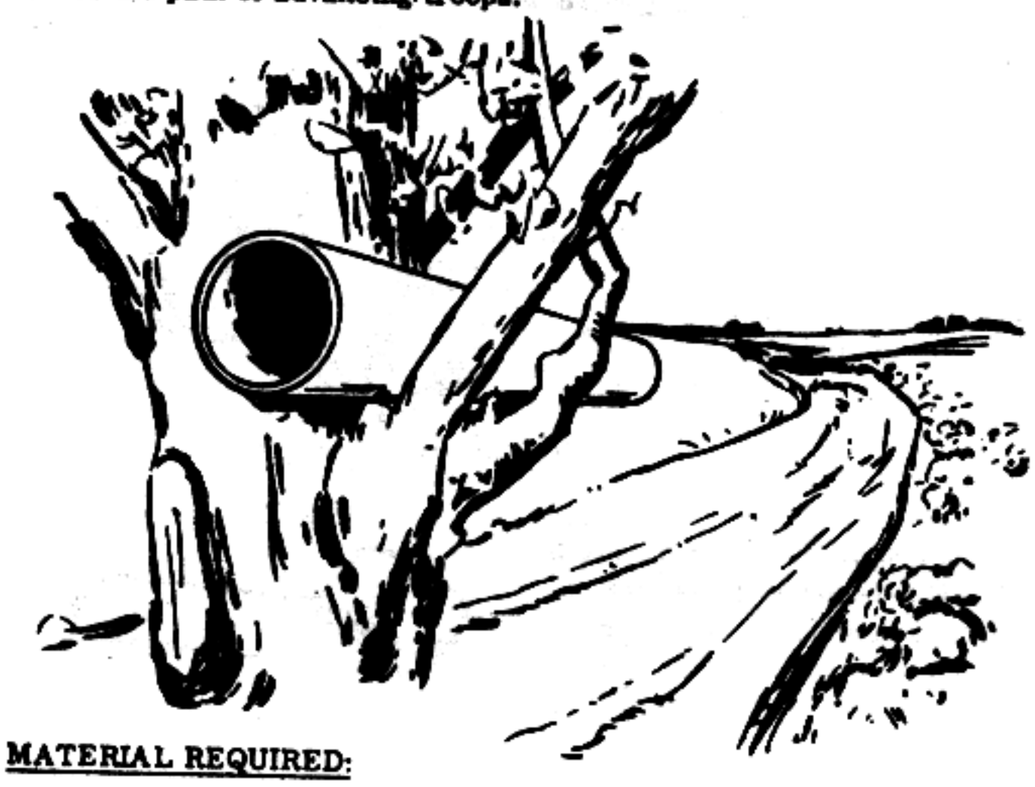
5. Place bolt in cartridge case so that it sticks out about the same length as the original bullet.



NOTE: If bolt does not fit snugly, force paper or match sticks between bolt and case, or wrap tape around bolt before inserting in case.

Section IV
63 No. 1
RECOILLESS LAUNCHER

A dual directional scrap fragment launcher which can be placed to cover the path of advancing troops.



MATERIAL REQUIRED:

Iron water pipe approximately 4 ft. (1 meter) long and 2 to 4 in. (5 to 10 cm) in diameter
Black powder (commercial) or salvaged artillery propellant about 1/2 lb. (200 gms)
Safety or improvised fuse (Section VI, No. 7) or improvised electrical igniter (Section VI, No. 2)
Stones and/or metal scrap chunks approximately 1/2 in. (1 cm) in diameter - about 1 lb. (400 gms) total
4 rags for wadding, each about 20 in. by 20 in. (50 cm by 50 cm)
Wire
Paper or rag

NOTE: Be sure that the water pipe has no cracks or flaws.

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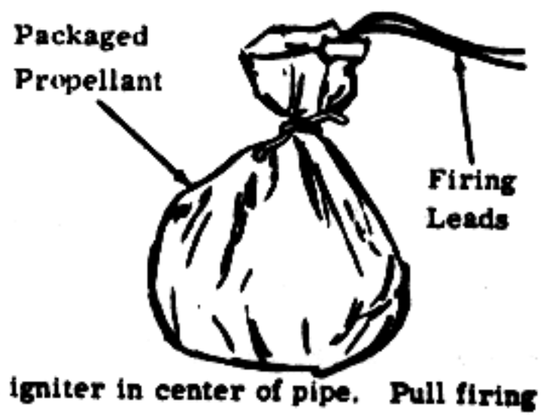
PROCEDURE:

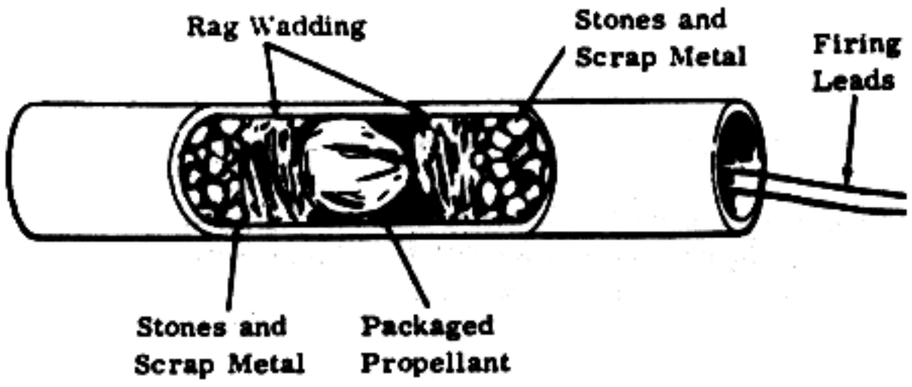
1. Place propellant and igniter in paper or rag and tie with string so contents cannot fall out.



2. Insert packaged propellant and igniter in center of pipe. Pull firing leads out one end of pipe.

3. Stuff a rag wad into each end of pipe and lightly tamp using a flat end stick.

4. Insert stones and/or scrap metal into each end of pipe. Be sure the same weight of material is used in each side.



5. Insert a rag wad into each end of the pipe and pack tightly as before.

HOW TO USE:

1. Place scrap mine in a tree or pointed in the path of the enemy. Attach igniter lead to the firing circuit. The recoilless launcher is now ready to fire.

2. If safety or improvised fuse is used instead of the detonator, place the fuse into the packaged propellant through a hole drilled in the center of the pipe. Light free end of fuse when ready to fire. Allow for normal delay time.

CAUTION: Scrap will be ejected from both ends of the launcher.

65 Section IV
No. 2

SHOTGUN GRENADE LAUNCHER

This device can be used to launch a hand grenade to a distance of 160 yards (150 meters) or more, using a standard 12 gauge shotgun.

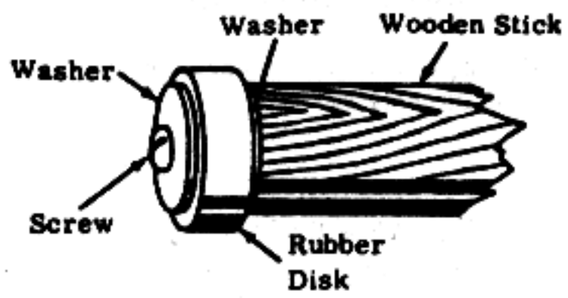
MATERIAL REQUIRED:

Grenade (Improvised pipe hand grenade, Section II, No. 1, may be used)
12 gauge shotgun
12 gauge shotgun cartridges
Two washers, (brass, steel, iron, etc.), having outside diameter of 5/8 in. (1-1/2 cm)
Rubber disk 3/4 in. (2 cm) in diameter and 1/4 in. (6 mm) thick (leather, neoprene, etc. can be used)
A 30 in. (75 cm) long piece of hard wood (maple, oak, etc.) approximately 5/8 in. (1-1/2 cm) in diameter. Be sure that wood will slide into barrel easily.
Tin can (grenade and its safety lever must fit into can)
Two wooden blocks about 2 in. (5 cm) square and 1-1/2 in. (4 cm) thick
One wood screw about 1 in. (2-1/2 cm) long
Two nails about 2 in. (5 cm) long
12 gauge wads, tissue paper, or cotton
Adhesive tape, string, or wire
Drill

PROCEDURE:

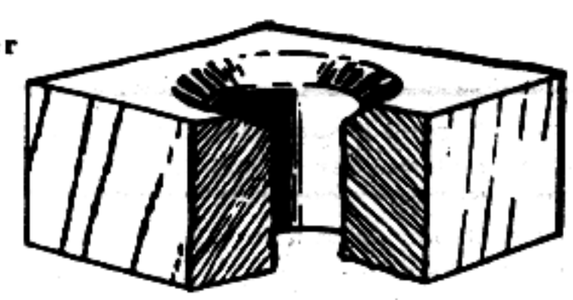
1. Punch hole in center of rubber disk large enough for screw to pass through.

2. Make push-rod as shown.



NOTE: Gun barrel is slightly less than 3/4 inch in diameter. If rubber disk does not fit in barrel, file or trim it very slightly. It should fit tightly.

3. Drill a hole through the center of one wooden block of such size that the push-rod will fit tightly Whittle a depression around the hole on one side approximately 1/8 in. (3 mm) and large enough for the grenade to rest in.



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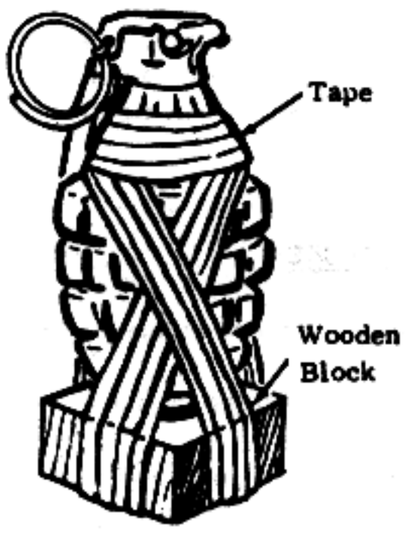
4. Place the base of the grenade in the depression in the wooden block. Securely fasten grenade to block by wrapping tape (or wire) around entire grenade and block.

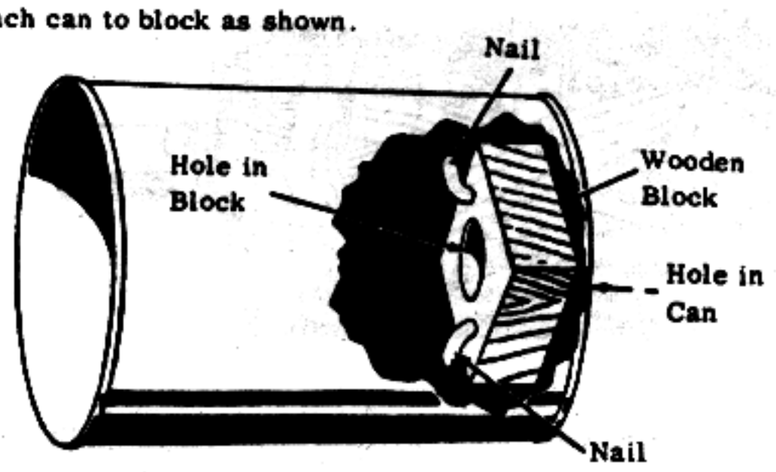
NOTE: Be sure that the tape (or wire) does not cover hole in block or interfere with the operation of the grenade safety lever.



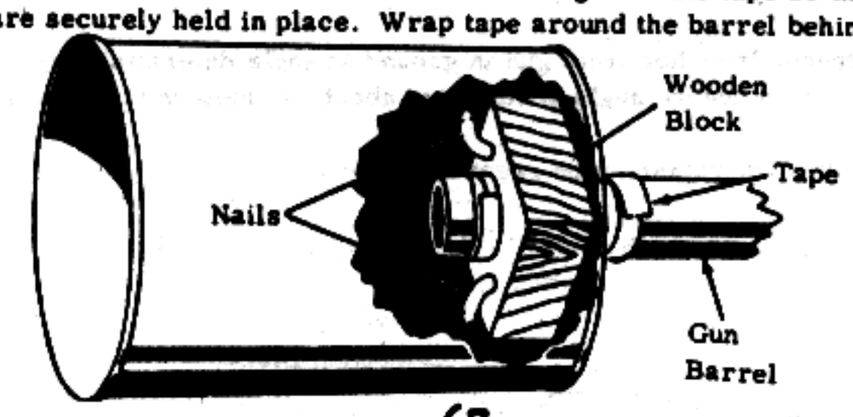
5. Drill hole through the center of the second wooden block, so that it will just slide over the outside of the gun barrel.

6. Drill a hole in the center of the bottom of the tin can the same size as the hole in the block.

7. Attach can to block as shown.



8. Slide the can and block onto the barrel until muzzle passes can open end. Wrap a small piece of tape around the barrel an inch or two from the end. Tightly wrapped string may be used instead of tape. Force the can and wooden block forward against the tape so that they are securely held in place. Wrap tape around the barrel behind the can



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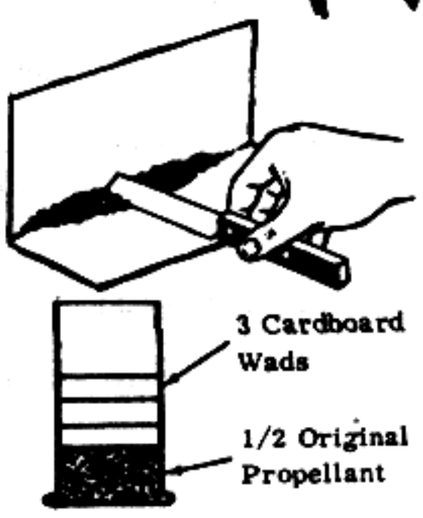
CAUTION: Be sure that the can is securely fastened to the gun barrel. If the can should become loose and slip down the barrel after the launcher is assembled, the grenade will explode after the regular delay time.

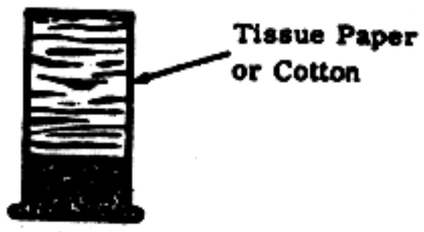
9. Remove crimp from a 12 gauge shotgun cartridge with pen knife. Open cartridge. Pour shot from shell. Remove wads and plastic liner if present.

10. Empty the propellant onto a piece of paper. Using a knife, divide the propellant in half. Replace half of the propellant into the cartridge case.

11. Replace the 12 gauge cardboard wads into cartridge case.



NOTE: If wads are not available, stuff tissue paper or cotton into the cartridge case. Pack tightly.



HOW TO USE:

Method I - When ordinary grenade is used:

1. Load cartridge in gun.

2. Push end of push-rod without the rubber disk into hole in wooden block fastened to grenade.

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3. Slowly push rod into barrel until it rests against the cartridge case and grenade is in can. If the grenade is not in the can, remove rod and cut to proper size. Push rod back into barrel.

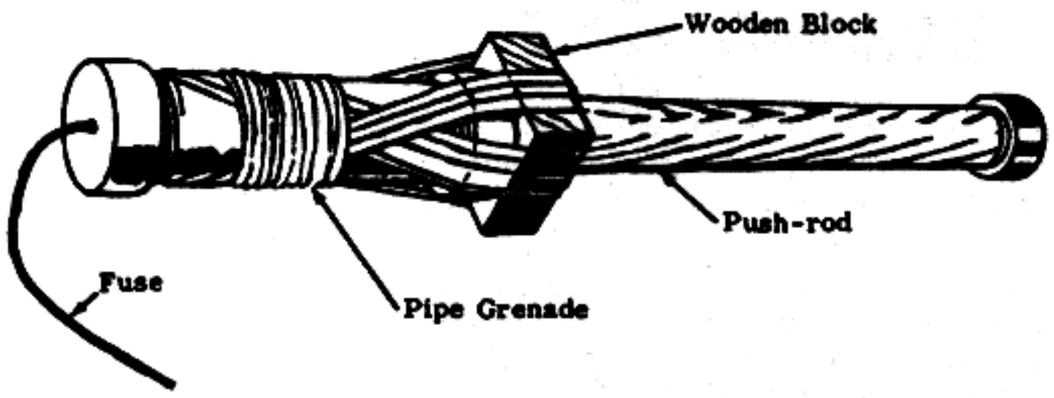
4. With can holding safety lever of grenade in place, carefully remove safety pin.

CAUTION: Be sure that the sides of the can restrain the grenade safety lever. If the safety lever should be released for any reason, grenade will explode after regular grenade delay time.

5. To fire grenade launcher, rest gun in ground at angle determined by range desired. A 45 degree angle should give about 150 meters (160 yds.)

Method II - When improvised pipe grenade is used:

An improvised pipe grenade (Section II, No. 1) may be launched in a similar manner. No tin can is needed.



1. Fasten the grenade to the block as shown above with the fuse hole at the end opposite the block.

2. Push end of push-rod into hole in wooden block fastened to grenade.

3. Push rod into barrel until it rests against cartridge case.

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4. Load cartridge in gun.

5. Follow step 5 of Method I.

6. Using a fuse with at least a 10 second delay, light the fuse before firing.

7. Fire when the fuse burns to 1/2 its original length.

70 Section IV No. 3
GRENADE LAUNCHER (37 MM CARDBOARD CONTAINER)

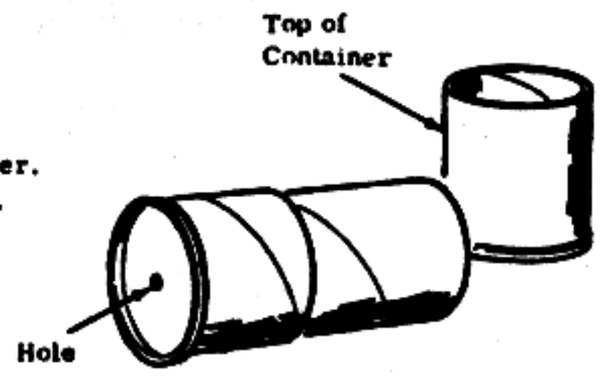
An improvised method of launching a standard grenade 150 yds. (133 meters) or an improvised grenade 90 yds. (81 meters) using a discarded cardboard ammunition container.

MATERIAL REQUIRED:

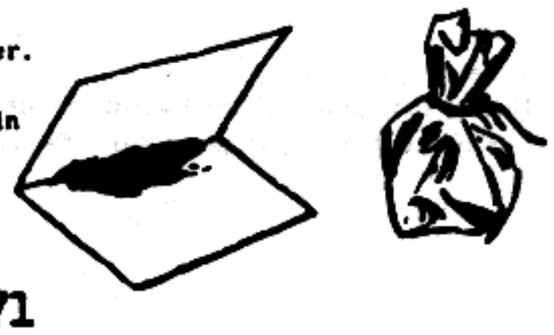
Heavy cardboard container with inside diameter of 2-1/2 to 3 in. (5-1/2 to 8 cm) and at least 12 in. (30 cm) long (ammunition container is suitable)
Black powder - 8 grams (124 grains) or less
Safety or improvised fuse (Section VI, No. 7)
Grenade (Improvised hand grenade, Section II, No. 1 may be used)
Rag, approximately 30 in. x 24 in. (75 cm x 60 cm)
Paper

CAUTION: 8 grams of black powder yield the maximum ranges. Do not use more than this amount. See Improvised Scale, Section VII, No. 8, for measuring.

PROCEDURE: METHOD 1 - If Standard Grenade is Used.



1. Discard top of container. Make small hole in bottom.



2. Place black powder in paper. Tie end with string so contents cannot fall out. Place package in container.

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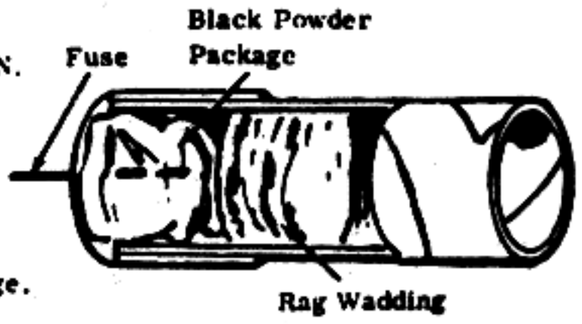
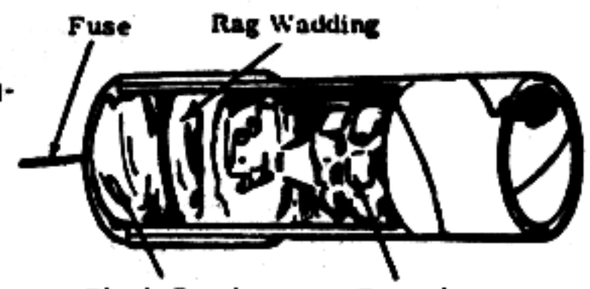


3. Insert rag wadding into container. Pack tightly with CAUTION.

4. Measure off a length of fuse that will give the desired delay. Thread this through hole in bottom of container so that it penetrates into the black powder package.

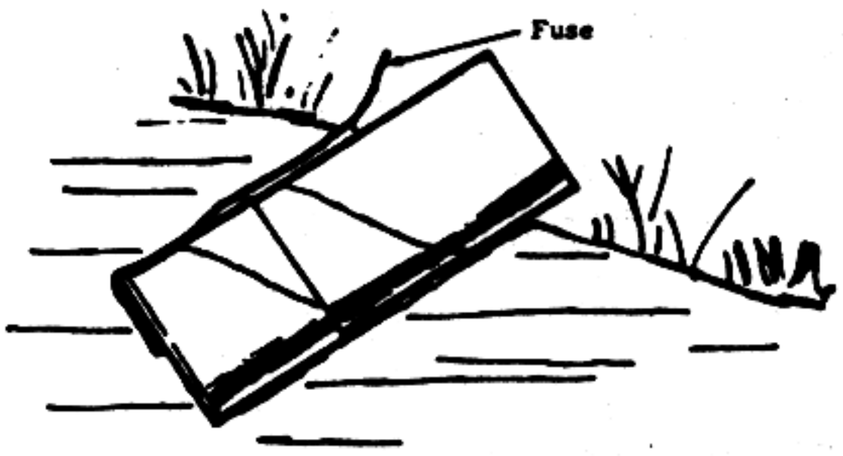
NOTE: If improvised fuse is used, be sure fuse fits loosely through hole in bottom of container.



5. Hold grenade safety lever and carefully withdraw safety pin from grenade. Insert grenade into container, lever end first.

CAUTION: If grenade safety lever should be released for any reason, grenade will explode after normal delay time.

6. Bury container about 6 in. (15 cm) in the ground at 30° angle, bringing fuse up alongside container. Pack ground tightly around container.



CAUTION: The tightly packed dirt helps to hold the tube together during the firing. Do not fire unless at least the bottom half of the container is buried in solidly packed dirt.

METHOD II - If Improvised Pipe Hand Grenade is Used.

1. Follow step 1 of above procedure.

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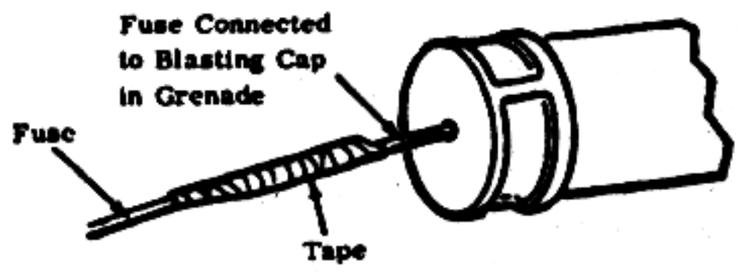
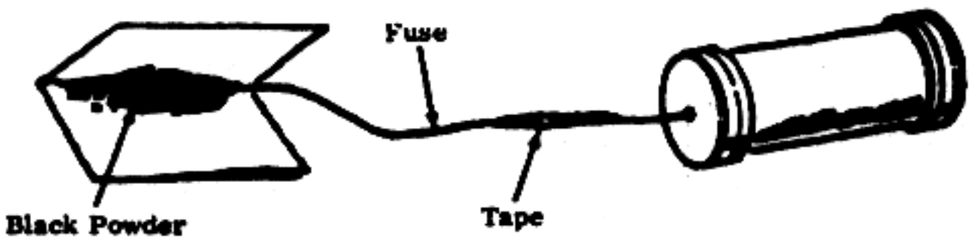
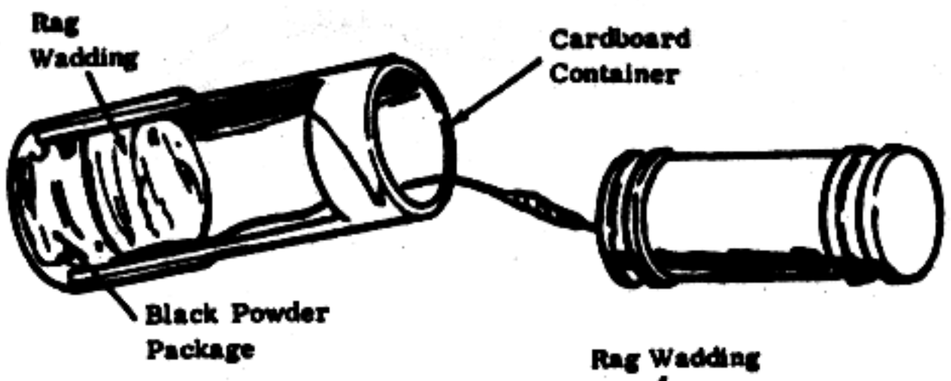
2. Measure off a piece of fuse at least as long as the cardboard container. Tape one end of this to the fuse from the blasting cap in the improvised grenade. Be sure ends of fuse are in contact with each other.



3. Place free end of fuse and black powder on piece of paper. Tie ends with string so contents will not fall out.

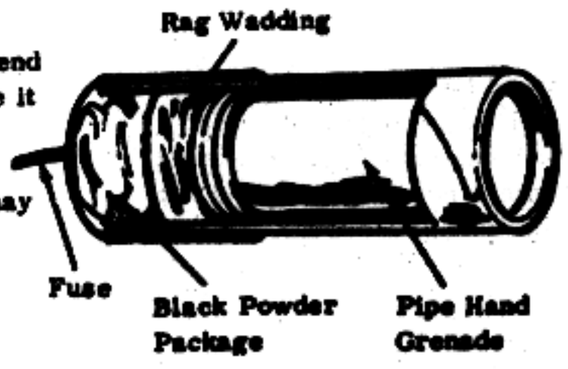


4. Place package in tube. Insert rag wadding. Pack so it fits snugly. Place pipe hand grenade into tube. Be sure it fits snugly.



5. Insert fuse through hole in end of cardboard container. Be sure it goes into black powder package.

NOTE: Cardboard container may be used for only one firing.



6. Follow step 6 of Method I.

HOW TO USE:

Light fuse when ready to fire.

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Section IV
No. 4

FIRE BOTTLE LAUNCHER

A device using 2 items (shotgun and chemical fire bottle) that can be used to start or place a fire 80 yards (72 meters) from launcher.

MATERIAL REQUIRED:

Standard 12 gauge or improvised shotgun (Section III, No. 2)
Improvised fire bottle (Section V, No. 1)
Tin can, about 4 in. (10 cm) in diameter and 5-1/2 in. (14 cm) high
Wood, about 3 in. x 3 in. x 2 in. (7-1/2 cm x 7-1/2 cm x 5 cm)
Nail, at least 3 in. (7-1/2 cm) long
Nuts and bolts or nails, at least 2-1/2 in. (6-1/2 cm) long
Rag
Paper
Drill

If Standard Shotgun is Used:

Hard wood stick, about the same length as shotgun barrel and about 5/8 in. (1-1/2 cm) in diameter. Stick need not be round.
2 washers (brass, steel, iron, etc.) having outside diameter of 5/8 in. (1-1/2 cm)
One wood screw about 1 in. (2-1/2 cm) long
Rubber disk, 3/4 in. (2 cm) in diameter and 1/4 in. (6 mm) thick, leather, cardboard, etc. can be used.
12 gauge shotgun ammunition

If Improvised Shotgun is Used:

Fuse, safety or improvised fast burning (Section VI, No. 7)
Hard wood stick, about the same length as shotgun barrel and 3/4 in. (2 cm) in diameter
Black powder - 9 grams (135 grains). See Section VII, No. 8,

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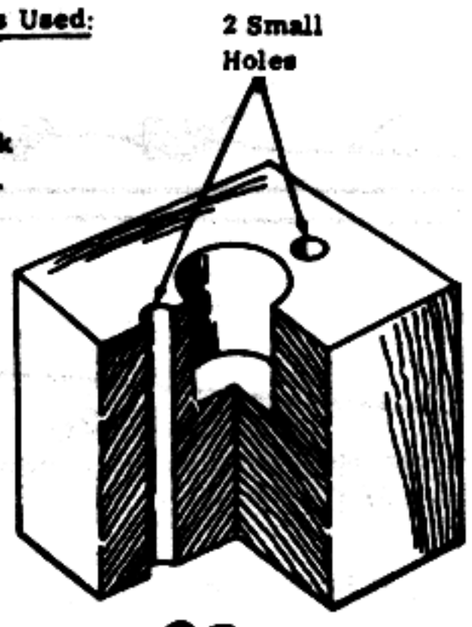
PROCEDURE:

METHOD I - If Improvised Shotgun is Used:

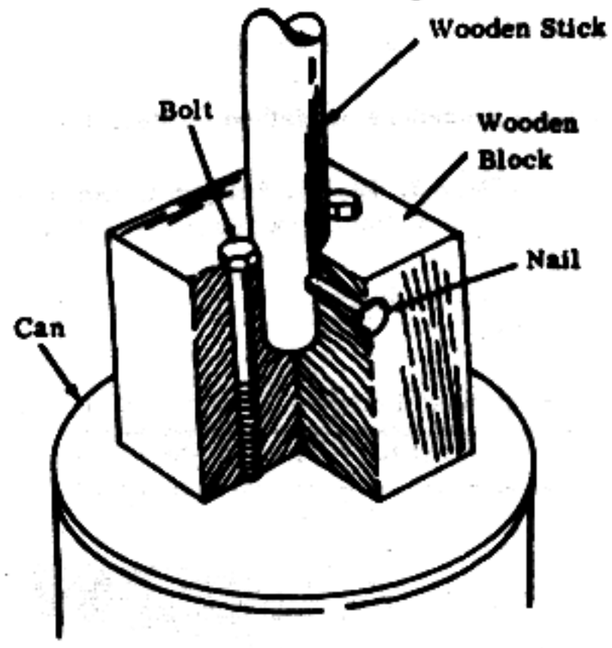
1. Drill hole in center of wood block approximately 1 in. (2-1/2 cm) deep. Hole should have approximately the same diameter as the wooden stick.



2. Drill 2 small holes on opposite sides of the wooden block. Hole should be large enough for bolts to pass through.

3. Fasten can to block with nuts and bolts.

NOTE: Can may also be securely fastened to block by hammering several nails through can and block. Do not drill holes, and be careful not to split wood.



4. Place wooden stick into hole in wooden block. Drill small hole (same diameter as that of 3 in. nail) through wooden block and through wooden stick. Insert nail in hole.

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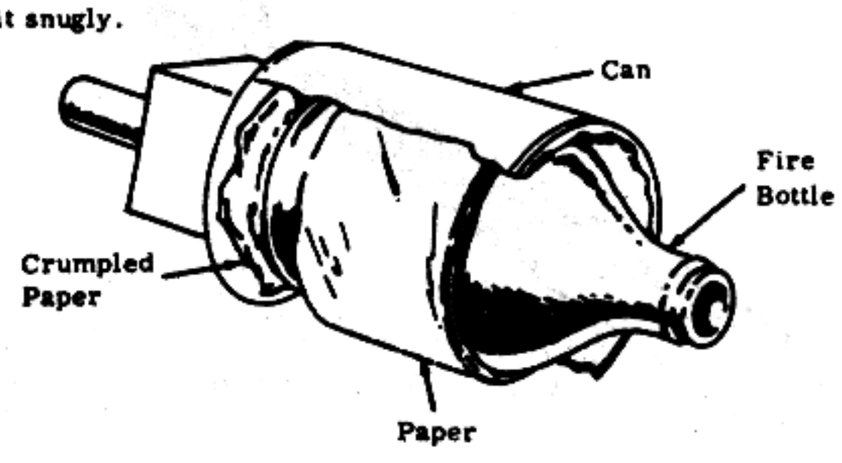
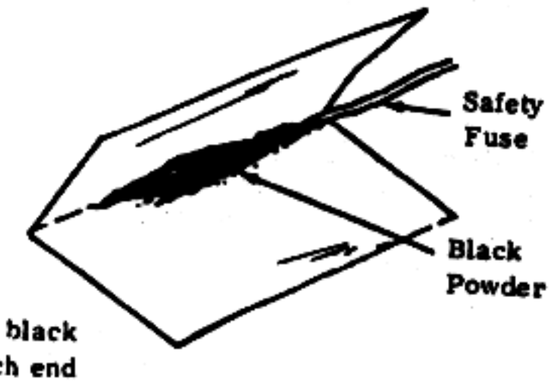
5. Crumple paper and place in bottom of can. Place another piece of paper around fire bottle and insert in can. Use enough paper so that bottle will fit snugly.

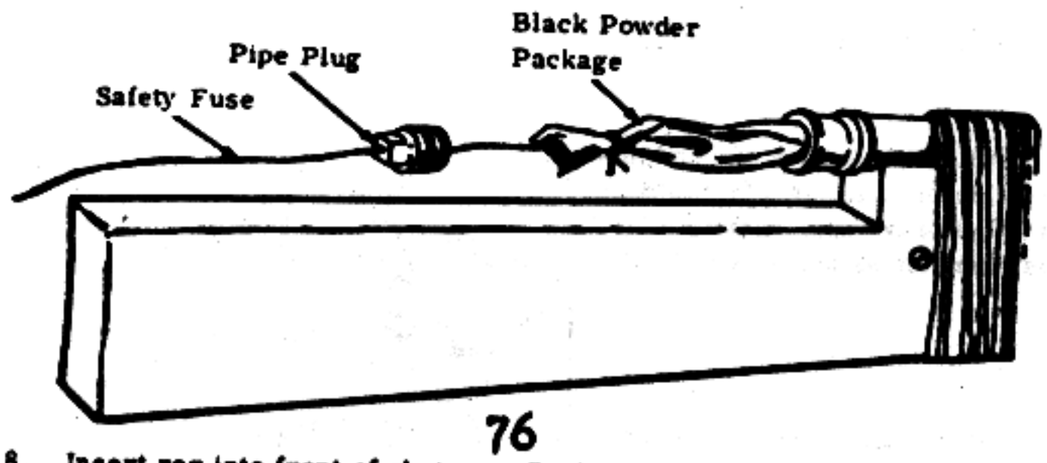




6. Place safety fuse and black powder on paper. Tie each end with string.

7. Thread fuse through hole in plug. Place powder package in rear of shotgun. Screw plug finger tight into coupling.

NOTE: Hole in plug may have to be enlarged for fuse.



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8. Insert rag into front of shotgun. Pack rag against powder package with stick. USE CAUTION.

METHOD II - If Standard Shotgun is Used:

1. Follow Steps 1 and 2, Shotgun Grenade Launcher, Section IV, No. 2.

2. Follow procedure of Method I, Steps 1 - 5.

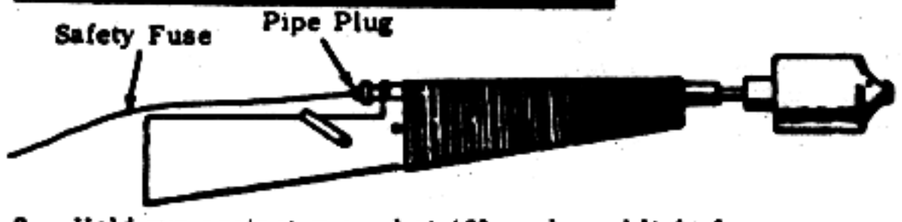
3. Follow Steps 9, 10, 11, Shotgun Grenade Launcher, Section IV, No. 2, using 1/3 of total propellant instead of 1/2.

4. Load cartridge in gun.

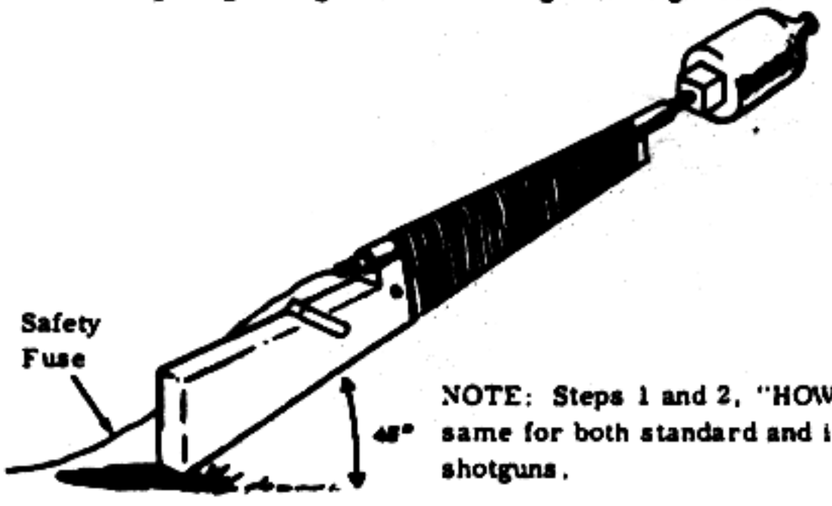
HOW TO USE:

1. Insert stick and holder containing chemical fire bottle.

CAUTION: Do not tilt muzzle downward.



2. Hold gun against ground at 45° angle and light fuse.



NOTE: Steps 1 and 2, "HOW TO USE," same for both standard and improvised shotguns.

CAUTION: Severe burns may result if bottle shatters when fired. If possible, obtain a bottle identical to that being used as the fire bottle. Fill about 2/3 full of water and fire as above. If bottle shatters when fired instead of being launched intact, use a different type of bottle.

Section IV
77 No. 5
GRENADE LAUNCHERS

A variety of grenade launchers can be fabricated from metal pipes and fittings. Ranges up to 600 meters (660 yards) can be obtained depending on length of tube, charge, number of grenades, and angle of firing.

MATERIAL REQUIRED:

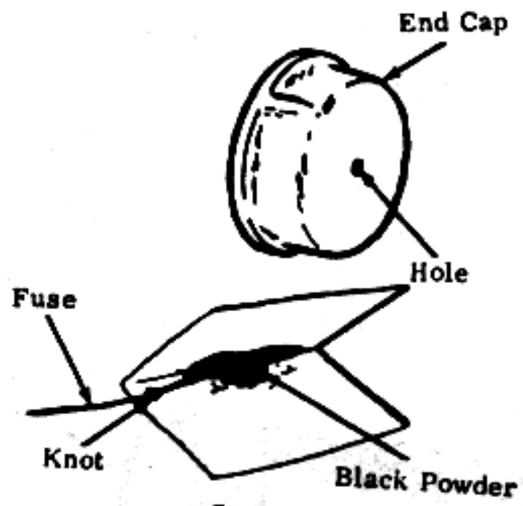
Metal pipe, threaded on one end and approximately 2-1/2 in. (6-1/4 cm) in diameter and 14 in. to 4 ft. (35 cm to 119 cm) long depending on range desired and number of grenades used.
End cap to fit pipe
Black powder, 15 to 50 gm, approximately 1-1/4 to 4-1/4 tablespoons (Section I, No. 3)
Safety fuse, fast burning improvised fuse (Section VI, No. 7) or improvised electric bulb initiator (Section VI, No. 1 Automobile light bulb is needed)
Grenade(s) - 1 to 6
Rag(s) - about 30 in. x 30 in. (75 cm x 75 cm) and 20 in. x 20 in. (55 cm x 55 cm)
Drill
String

NOTE: Examine pipe carefully to be sure there are no cracks or other flaws.

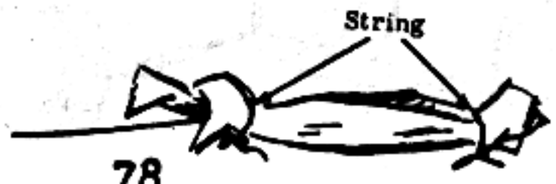
PROCEDURE:

METHOD I - If Fuse is Used:

1. Drill small hole through center of end cap.



2. Make small knot near one end of fuse. Place black powder and knotted end of fuse in paper and tie with string.



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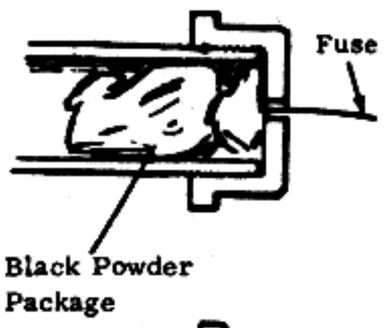
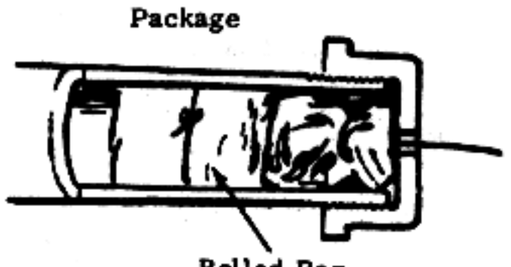
3. Thread fuse through hole in end cap and place package in end cap. Screw end cap onto pipe, being careful that black powder package is not caught between the threads.



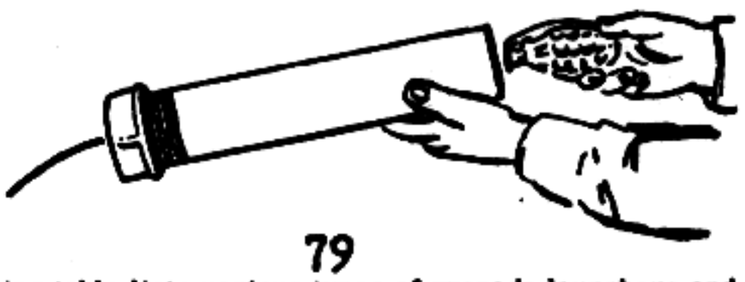
4. Roll rag wad so that it is about 6 in. (15 cm) long and has approximately the same diameter as the pipe. Push rolled rag into open-end of pipe until it rests against black powder package.



5. Hold grenade safety lever in place and carefully withdraw safety pin.

CAUTION: If grenade safety lever is released for any reason, grenade will explode after regular time. (4 - 5 sec.)

6. Holding safety lever in place, carefully push grenade into pipe, lever end first, until it rests against rag wad.



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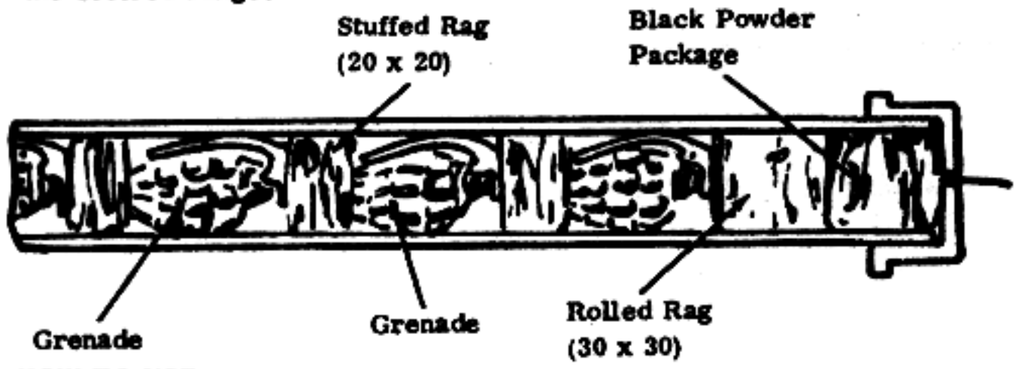
7. The following table lists various types of grenade launchers and their performance characteristics.

DESIRED RANGE	NO. OF GRENADES LAUNCHED	BLACK POWDER CHARGE	PIPE LENGTH	FIRING ANGLE
250 m	1	15 gm	14"	30°
500 m	1	50 gm	48"	10°
600 m (a)	1	50 gm	48"	30°
200 m	6 (b)	25 gm	48"	30°

(a) For this range, an additional delay is required. See Section VI, No. 11 and 12.

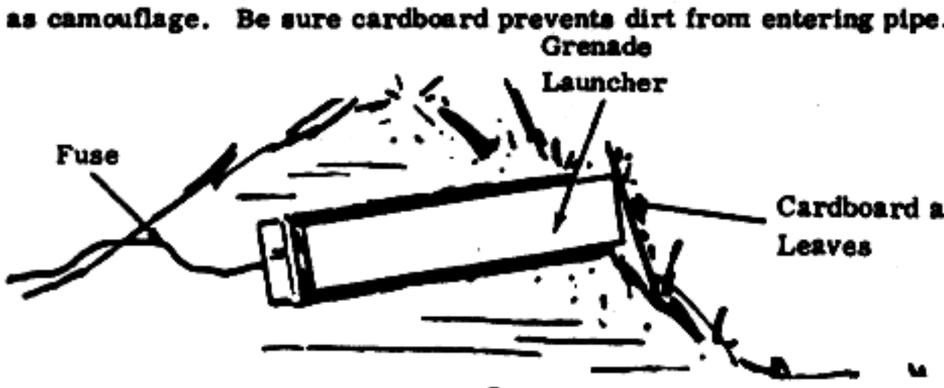
(b) For multiple grenade launcher, load as shown.

NOTE: Since performance of different black powder varies, fire several test rounds to determine the exact amount of powder necessary to achieve the desired range.



HOW TO USE:

1. Bury at least 1/2 of the launcher pipe in the ground at desired angle. Open end should face the expected path of the enemy. Muzzle may be covered with cardboard and a thin layer of dirt and/or leaves as camouflage. Be sure cardboard prevents dirt from entering pipe.



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NOTE: The 14 in. launcher may be hand held against the ground instead of being buried.

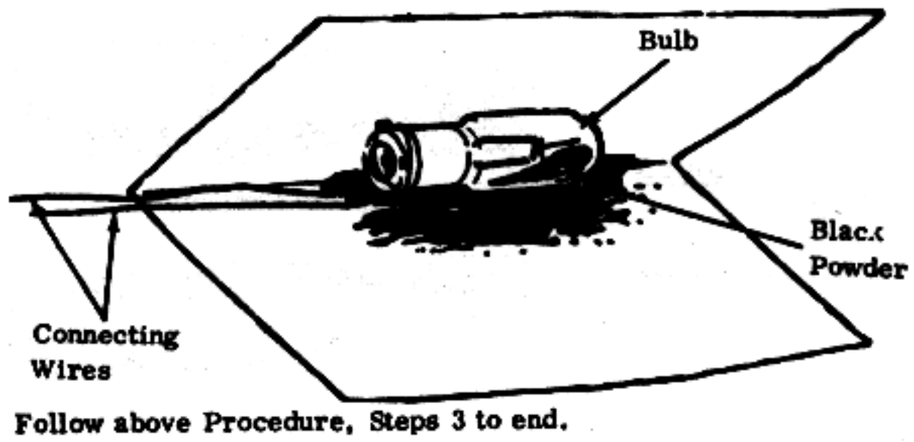
2. Light fuse when ready to fire.

METHOD II - If Electrical Igniter is Used:

NOTE: Be sure that bulb is in good operating condition.

1. Prepare electric bulb initiator as described in Section VI, No. 1.

2. Place electric initiator and black powder charge in paper. Tie ends of paper with string.



3. Follow above Procedure, Steps 3 to end.

HOW TO USE:

1. Follow above How to Use, Step 1.

2. Connect leads to firing circuit. Close circuit when ready to fire.

Section IV

81 No. 6

60 MM MORTAR PROJECTILE LAUNCHER

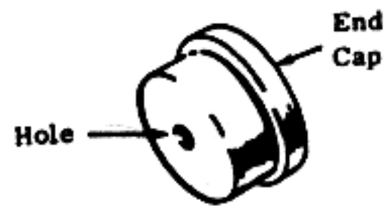
A device to launch 60 mm mortar rounds using a metal pipe 2-1/2 in. (6 cm) in diameter and 4 ft. (120 cm) long as the launching tube.

MATERIAL REQUIRED:

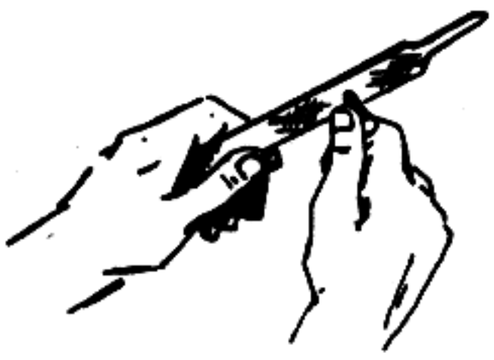
Mortar, projectile (60 mm) and charge increments
Metal pipe 2-1/2 in. (6 cm) in diameter and 4 ft. (120 cm) long, threaded on one end
Threaded end cap to fit pipe
Bolt, 1/8 in. (3 mm) in diameter and at least 1 in. (2-1/2 cm) long
Two (2) nuts to fit bolt
File
Drill

PROCEDURE:

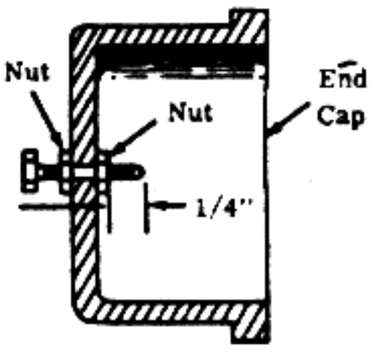
1. Drill hole 1/8 in. (3 mm) in diameter through center of end cap.



2. Round off end of bolt with file.



3. Place bolt through hole in end cap. Secure in place with nuts as illustrated.



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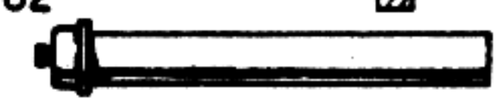
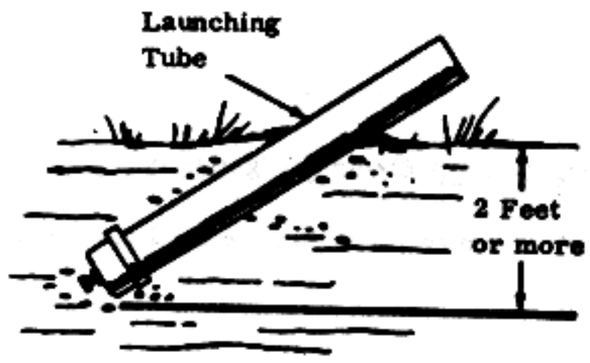
4. Screw end cap onto pipe tightly. Tube is now ready for use.

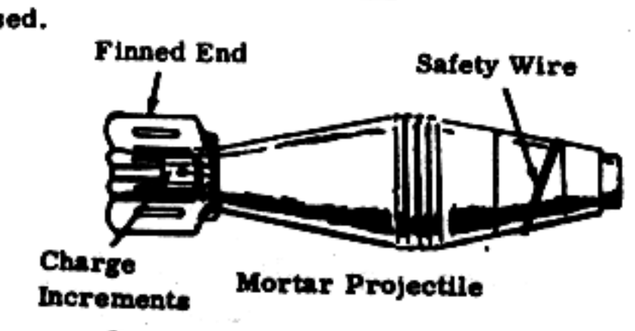


HOW TO USE:

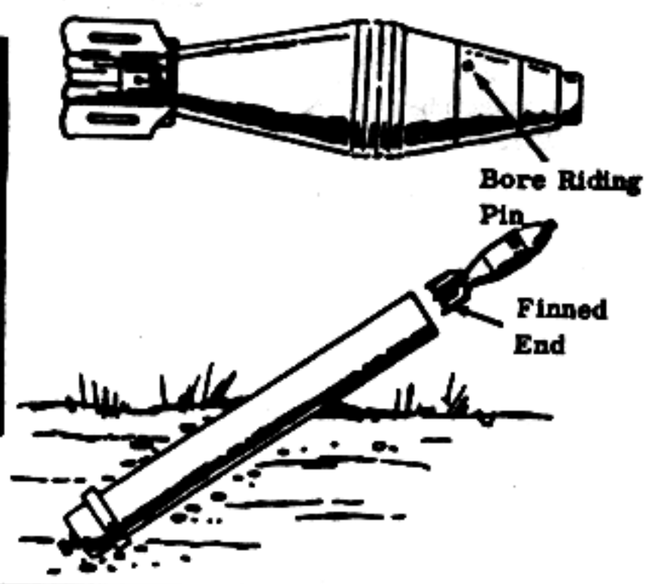
1. Bury launching tube in ground at desired angle so that bottom of tube is at least 2 ft. (60 cm) underground. Adjust the number of increments in rear finned end of mortar projectile. See following table for launching angle and number of increments used.



2. When ready to fire, withdraw safety wire from mortar projectile. Drop projectile into launching tube, FINNED END FIRST.



CAUTION: Be sure bore riding pin is in place in fuse when mortar projectile is dropped into tube. A live mortar round could explode in the tube if the fit is loose enough to permit the bore riding pin to come out partway.



CAUTION: The round will fire as soon as the projectile is dropped into tube. Keep all parts of body behind the open end of the tube.

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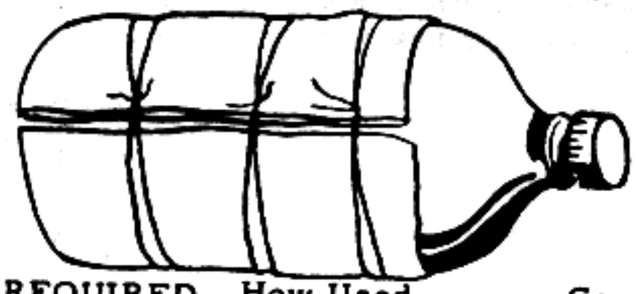
DESIRED RANGE (YARDS)	MAXIMUM HEIGHT MORTAR WILL REACH (YARDS)	REQUIRED ANGLE OF ELEVATION OF TUBE (MEASURED FROM HORIZONTAL DEGREES)	CHARGE - NUMBER OF INCREMENTS
150	25	40	0
300	50	40	1
700	150	40	2
1000	225	40	3
1500	300	40	4
125	75	60	0
300	125	60	1
550	250	60	2
1000	375	60	3
1440	600	60	4
75	100	80	0
150	200	80	1
300	350	80	2
400	600	80	3
550	750	80	4

Section V

84 No. 1

CHEMICAL FIRE BOTTLE

This incendiary bottle is self-igniting on target impact.



MATERIALS REQUIRED	How Used	Common Source
Sulphuric Acid	Storage Batteries	Motor Vehicles
Gasoline	Motor Fuel	Gas Station or Motor Vehicles
Potassium Chlorate	Medicine	Drug Store
Sugar	Sweetening Foods	Food Store

Glass bottle with stopper (roughly 1 quart size).
Small Bottle or jar with lid.
Rag or absorbent paper (paper towels, newspaper).
String or rubber bands.

PROCEDURE

1. Sulphuric Acid Must be Concentrated. If battery acid or other dilute acid is used, concentrate it by boiling until dense white fumes are given off. Container used should be of enamelware or oven glass.

CAUTION

Sulphuric acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Fumes are also dangerous and should not be inhaled.

2. Remove the acid from heat and allow to cool to room temperature.

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3. Pour gasoline into the large (1 quart) bottle until it is approximately 2/3 full.

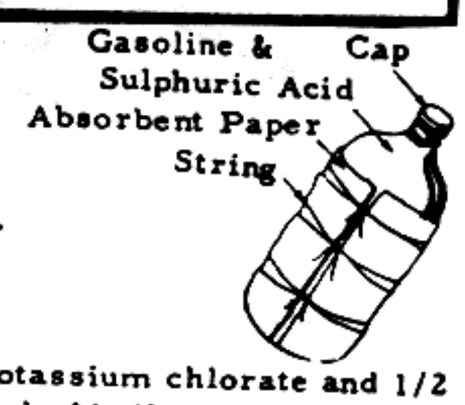
4. Add concentrated sulphuric acid to gasoline slowly until the bottle is filled to within 1" to 2" from top. Place the stopper on the bottle.

5. Wash the outside of the bottle thoroughly with clear water.

CAUTION

If this is not done, the fire bottle may be dangerous to handle during use.

6. Wrap a clean cloth or several sheets of absorbent paper around the outside of the bottle. Tie with string or fasten with rubber bands.

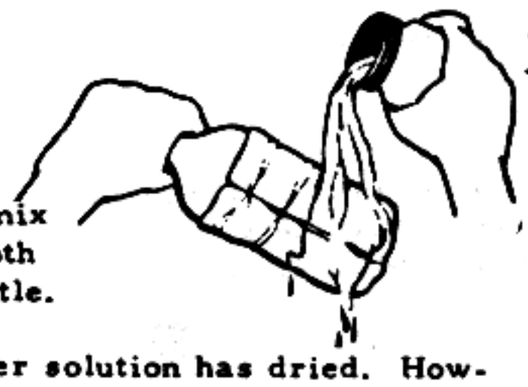


7. Dissolve 1/2 cup (100 gm) of potassium chlorate and 1/2 cup (100 gm) of sugar in one cup (250 cc) of boiling water.

8. Allow the solution to cool, pour into the small bottle and cap tightly. The cooled solution should be approx. 2/3 crystals and 1/3 liquid. If there is more liquid than this, pour off excess before using.

CAUTION

Store this bottle separately from the other bottle.



HOW TO USE

1. Shake the small bottle to mix contents and pour onto the cloth or paper around the large bottle.

Bottle can be used wet or after solution has dried. However, when dry, the sugar - Potassium chlorate mixture is very sensitive to spark or flame and should be handled accordingly.

2. Throw or launch the bottle. When the bottle breaks against a hard surface (target) the fuel will ignite.

Use With Molotov Cocktail

Tape the "match end tab" of the igniter to the neck of the molotov cocktail.

Grasp the "cover end tab" and pull sharply or quickly to ignite.

General Use

The book match igniter can be used by itself to ignite flammable liquids, fuse cords and similar items requiring hot ignition.

CAUTION

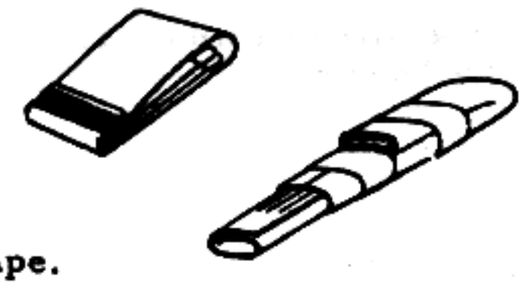
Store matches and completed igniters in moistureproof containers such as rubber or plastic bags until ready for use. Damp or wet paper book matches will not ignite.

Section V

86 No. 2

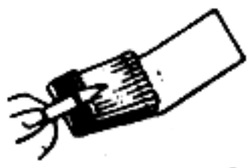
IGNITER FROM BOOK MATCHES

This is a hot igniter made from paper book matches for use with molotov cocktail and other incendiaries.



Material Required

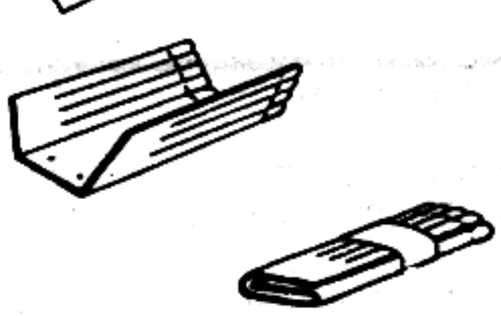
Paper book matches.
Adhesive or friction tape.



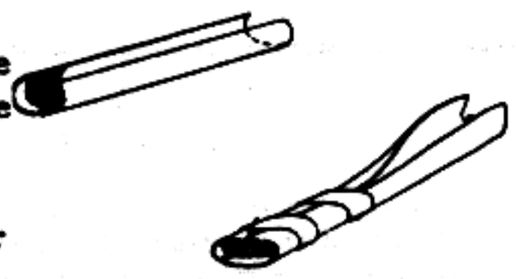
Procedure

1. Remove the staple(s) from match book and separate matches from cover.

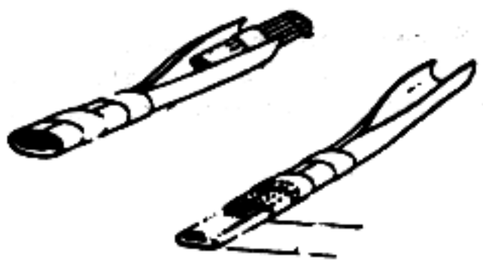
2. Fold and tape one row of matches.



3. Shape the cover into a tube with striking surface on the inside and tape. Make sure the folded cover will fit tightly around the taped match heads. Leave cover open at opposite end for insertion of the matches.



4. Push the taped matches into the tube until the bottom ends are exposed about 3/4 in. (2 cm).



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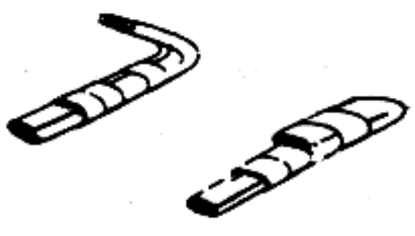
5. Flatten and fold the open end of the tube so that it laps over about 1 in. (2-1/2 cm); tape in place.



Section V

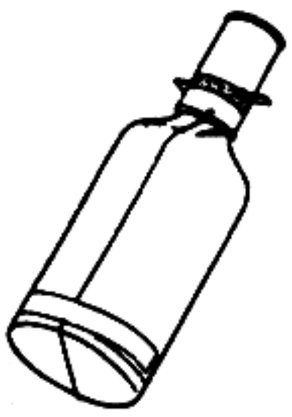
88 No. 3

MECHANICALLY INITIATED FIRE BOTTLE

The mechanically initiated Fire Bottle is an incendiary device which ignites when thrown against a hard surface.

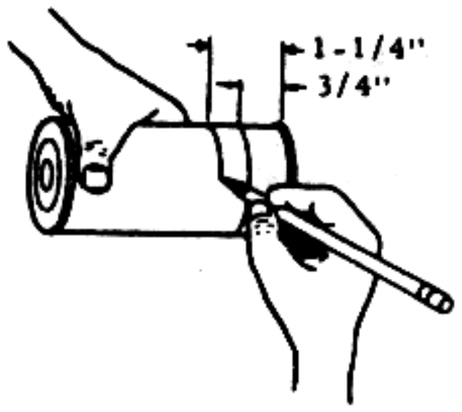
MATERIALS REQUIRED

Glass jar or short neck bottle with a leakproof lid or stopper.
"Tin" can or similar container just large enough to fit over the lid of the jar.
Coil spring (compression) approximately 1/2 the diameter of the can and 1 1/2 times as long.
Gasoline
Four (4) "blue tip" matches
Flat stick or piece of metal (roughly 1/2" x 1/16" x 4")
Wire or heavy twine
Adhesive tape

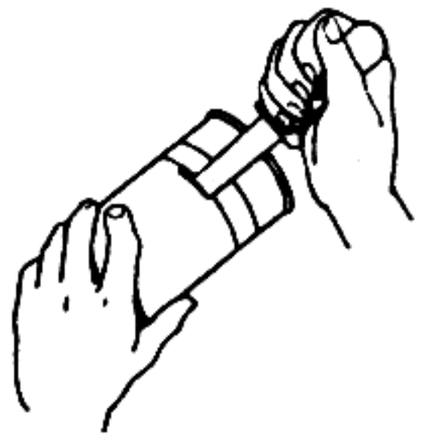


PROCEDURE

1. Draw or scratch two lines around the can - one 3/4" (19 mm) and the other 1 1/4" (30 mm) from the open end.



2. Cut 2 slots on opposite sides of the tin can at the line farthest from the open end. Make slots large enough for the flat stick or piece of metal to pass through.



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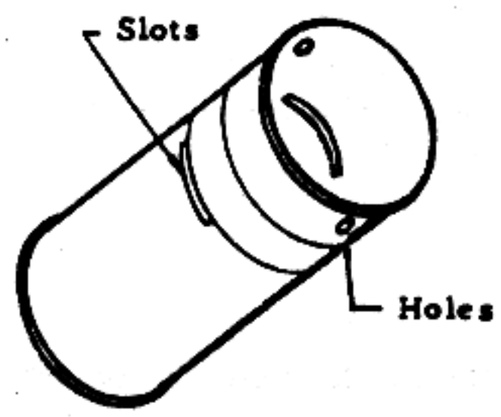
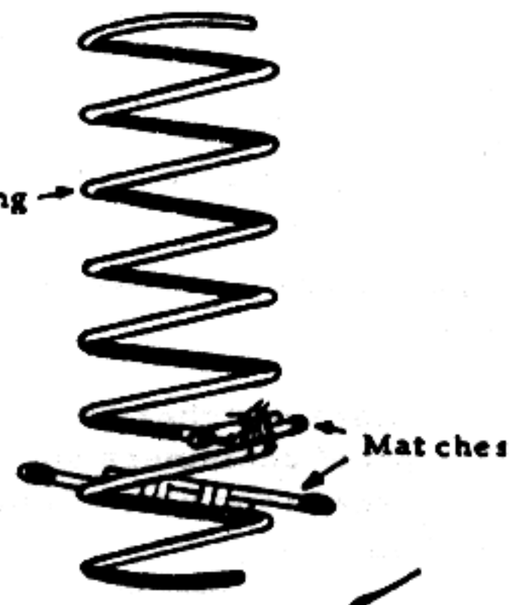
3. Punch 2 small holes just below the rim of the open end of the can.

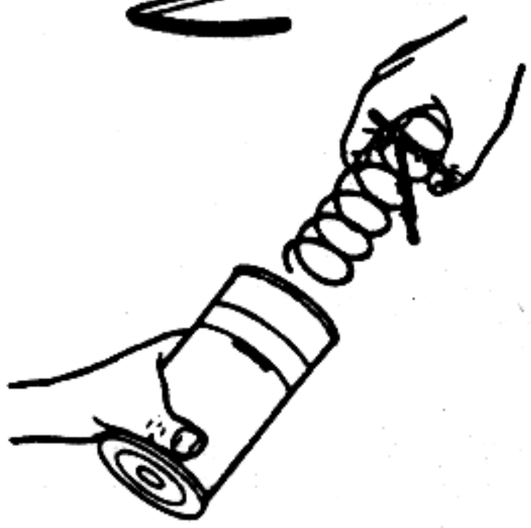


4. Tape blue tip matches together in pairs. The distance between the match heads should equal the inside diameter of the can. Two pairs are sufficient.



5. Attach paired matches to second and third coils of the spring, using thin wire.

6. Insert the end of the spring opposite the matches into the tin can.



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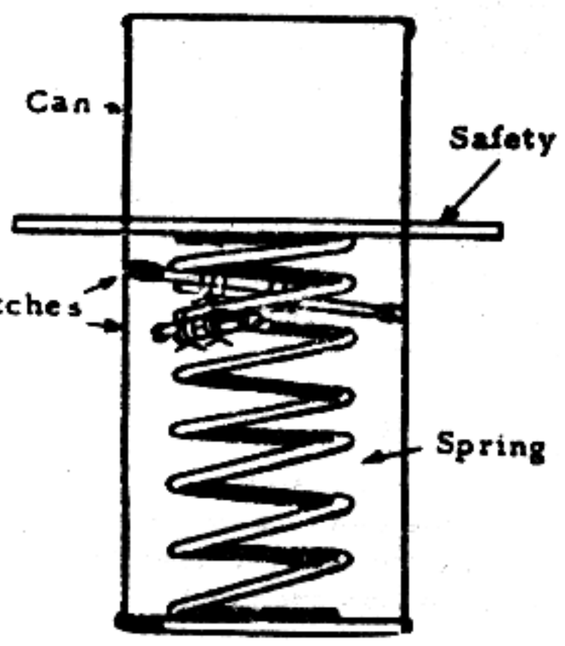
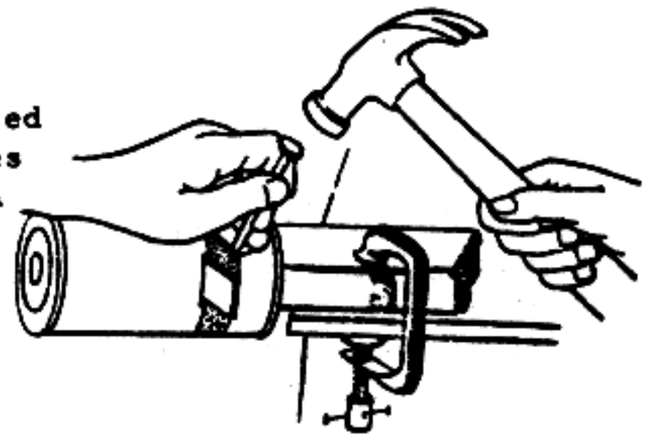
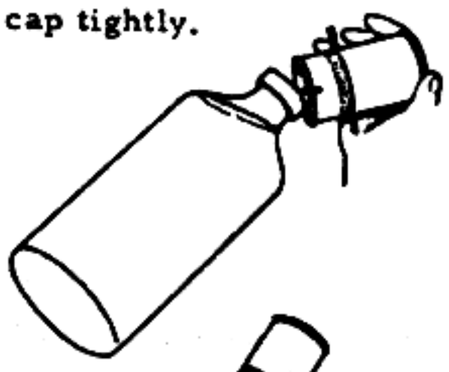
7. Compress the spring until the end with the matches passes the slot in the can. Pass the flat stick or piece of metal through slots in can to hold spring in place. This acts as a safety device.



8. Punch many closely spaced small holes between the lines marked on the can to form a striking surface for the matches. Be careful not to seriously deform can.



9. Fill the jar with gasoline and cap tightly.



10. Turn can over and place over the jar so that the safety stick rests on the lid of the jar.

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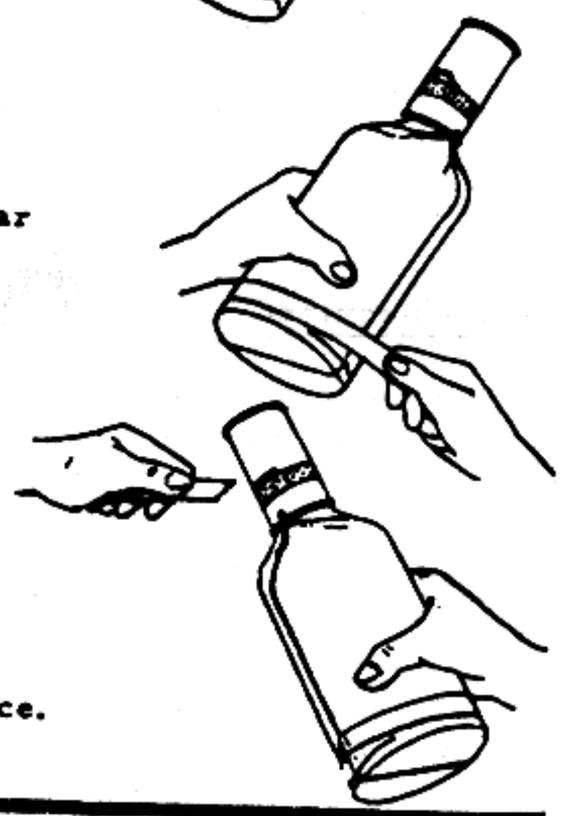
11. Pass wire or twine around the bottom of the jar. Thread ends through holes in can and bind tightly to jar.



12. Tape wire or cord to jar near the bottom.

HOW TO USE

1. Carefully withdraw flat safety stick.

2. Throw jar at hard surface.

CAUTION:

DO NOT REMOVE SAFETY STICK UNTIL READY TO THROW FIRE BOTTLE.

The safety stick, when in place, prevents ignition of the fire bottle if it should accidentally be broken.

92 Section V
No. 4

GELLED FLAME FUELS

Gelled or paste type fuels are often preferable to raw gasoline for use in incendiary devices such as fire bottles. This type fuel adheres more readily to the target and produces greater heat concentration.

Several methods are shown for gelling gasoline using commonly available materials. The methods are divided into the following categories based on the majo. ingredient:

4.1 Lye Systems

4.2 Lye-Alcohol Systems

4.3 Soap-Alcohol Systems

4.4 Egg White Systems

4.5 Latex Systems

4.6 Wax Systems

4.7 Animal Blood Systems

93 Section V No. 4.1

GELLED FLAME FUELS
LYE SYSTEMS

Lye (also known as caustic soda or Sodium Hydroxide) can be used in combination with powdered rosin or castor oil to gel gaso line for use as a flame fuel which will adhere to target surfaces.

NOTE: This fuel is not suitable for use in the chemical (Sulphuric Acid) type of fire bottle (Section V, No.1). The acid will react with the lye and break down the gel.

MATERIALS REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
60	Gasoline	Motor fuel	Gas station or motor vehicle
2 (flake) or 1 (powder)	Lye	Drain cleaner, making of soap	Food store Drug store
15	Rosin or Castor Oil	Manufacturing Paint & Varnish Medicine	Naval stores Industry Food and Drug Stores

PROCEDURE:

CAUTION: Make sure that there are no open flames when mixing the flame fuel. NO SMOKING! in the area

1. Pour gasoline into jar, bottle or other container. (DO NOT USE AN ALUMINUM CONTAINER.)
2. If rosin is in cake form, crush into small pieces.
3. Add rosin or castor oil to the gasoline and stir for about five (5) minutes to mix thoroughly.
4. In a second container (NOT ALUMINUM) add lye to an equal volume of water slowly with stirring.

CAUTION: Lye solution can burn skin and destroy clothing. If any is spilled, wash away immediately with large quantities of water.

5. Add lye solution to the gasoline mix and stir until mixture thickens (about one minute).

NOTE: The sample will eventually thicken to a very firm paste. This can be thinned, if desired, by stirring in additional gasoline.

94 Section V No. 4.2

GELLED FLAME FUELS

LYE-ALCOHOL SYSTEMS

Lye (also known as caustic soda or Sodium Hydroxide) can be used in combination with alcohol and any of several fats to gel gasoline for use as a flame fuel.

NOTE: This fuel is not suitable for use in the chemical (Sulphuric Acid) type of fire bottle (Section V, No. 1). The acid will react with the lye and break down the gel.

MATERIALS REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
60	Gasoline	Motor fuel	Gas station or motor vehicles
2 (flake) or 1 (powder)	Lye	Drain cleaner Making of soap	Food store Drug store
3	Ethyl Alcohol	Whiskey Medicine	Liquor store Drug store

NOTE: Methyl (wood) alcohol or isopropyl (rubbing) alcohol can be substituted for ethyl alcohol, but their use produces softer gels.

14	Tallow	Food Making of soap	Fat rendered by cooking the meat or suet of animals.

NOTE: The following can be substituted for the tallow:

(a) Wool grease (Lanolin) (very good) -- Fat extracted from sheep wool.
(b) Castor oil (good).
(c) Any vegetable oil (corn, cottonseed, peanut, linseed, etc.)
(d) Any fish oil
(e) Butter or oleomargarine

It is necessary when using substitutes (c) to (e) to double the given amount of fat and of lye for satisfactory bodying.

PROCEDURE:

CAUTION: Make sure that there are no open flames in the area when mixing flame fuels. NO SMOKING!

1. Pour gasoline into bottle, jar or other container. (DO NOT USE AN ALUMINUM CONTAINER).

2. Add Tallow (or substitute) to the gasoline and stir for about 1/2 minute to dissolve fat.

95

3. Add alcohol to the gasoline mixture.

4. In a separate container (NOT ALUMINUM) slowly add lye to an equal amount of water. Mixture should be stirred constantly while adding lye.

CAUTION: Lye solution can burn skin and destroy clothing. If any is spilled, wash away immediately with large quantities of water.

5. Add lye solution to the gasoline mixture and stir occasionally until thickened (about 1/2 hour).

NOTE: The mixture will eventually (1 to 2 days) thicken to a very firm paste. This can be thinned, if desired, by stirring in additional gasoline.

Section V
96 No. 4.3

GELLED FLAME FUELS

SOAP-ALCOHOL SYSTEM

Common household soap can be used in combination with alcohol to gel gasoline for use as a flame fuel which will adhere to target surfaces.

MATERIAL REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
36	Gasoline	Motor fuel	Gas station, Motor vehicles
1	Ethyl Alcohol	Whiskey Medicine	Liquor store Drug store

NOTE: Methyl (wood) or isopropyl (rubbing) alcohols can be substituted for the whiskey.

20 (powdered) or 28 (flake)	Laundry soap	Washing clothes	Stores

NOTE: Unless the word "soap" actually appears somewhere on the container or wrapper, a washing compound is probably a detergent. These Can Not Be Used.

PROCEDURE:

CAUTION: Make sure that there are no open flames in the area when mixing flame fuels. NO SMOKING!

1. If bar soap is used, carve into thin flakes using a knife.

2. Pour alcohol and gasoline into a jar, bottle or other container and mix thoroughly.

3. Add soap powder or flakes to gasoline-alcohol mix and stir occasionally until thickened (about 15 minutes).

Section V
97 No. 4.4
GELLED FLAME FUELS

EGG SYSTEMS

The white of any bird egg can be used to gel gasoline for use as a flame fuel which will adhere to target surfaces.

MATERIALS REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
85	Gasoline	Motor fuel Stove fuel Solvent	Gas station Motor vehicles
14	Egg Whites	Food Industrial processes	Food store Farms
Any One Of The Following:			
1	Table Salt	Food Industrial processes	Sea water Natural brine Food store
3	Ground Coffee	Food	Coffee plant Food store
3	Dried Tea Leaves	Food	Tea plant Food store
3	Cocoa	Food	Cacao tree Food store
2	Sugar	Sweetening foods Industrial processes	Sugar cane Food store
1	Saltpeter (Niter) (Potassium Nitrate)	Pyrotechnics Explosives Matches Medicine	Natural Deposits Drug store
1	Epsom salts	Medicine Mineral water Industrial processes	Natural deposits Kieserite Drug store Food store
2	Washing soda (Sal soda)	Washing cleaner Medicine Photography	Food store Drug store Photo supply store

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1 1/2	Baking Soda	Baking Manufacture of: Beverages, Mineral waters and Medicines	Food store Drug store
1 1/2	Aspirin	Medicine	Drug store Food store

PROCEDURE:

CAUTION: Make sure that there are no open flames in the area when mixing flame fuels. NO SMOKING!

1. Separate egg white from yolk. This can be done by breaking the egg into a dish and carefully removing the yolk with a spoon.

NOTE: DO NOT GET THE YELLOW EGG YOLK MIXED INTO THE EGG WHITE. If egg yolk gets into the egg white, discard the egg.

2. Pour egg white into a jar, bottle, or other container and add gasoline.

3. Add the salt (or other additive) to the mixture and stir occasionally until gel forms (about 5 to 10 minutes).

NOTE: A thicker gelled flame fuel can be obtained by putting the capped jar in hot (65°C) water for about 1/2 hour and then letting them cool to room temperature. (DO NOT HEAT THE GELLED FUEL CONTAINING COFFEE).

Section V
99 No. 4.5
GELLED FLAME FUELS

LATEX SYSTEMS

Any milky white plant fluid is a potential source of latex which can be used to gel gasoline

MATERIALS REQUIRED:

Ingredient	How Used	Common Source
Gasoline	Motor fuel Solvent	Gas station Motor vehicle
Latex, commerical or natural	Paints Adhesives	Natural from tree or plant Rubber cement
One of the Following Acids:		
Acetic Acid (Vinegar)	Salad dressing Developing film	Food stores Fermented apple cider Photographic supply
Sulfuric Acid (Oil of Vitriol)	Storage batteries Material processing	Motor vehicles Industrial plants
Hydrochloric Acid (Muriatic Acid)	Petroleum wells Pickling and metal cleaning Industrial processes	Hardware store Industrial plants

NOTE: If acids are not available, use acid salt (alum, sulfates and chlorides other than sodium or potassium). The formic acid from crushed red ants can also be used.

PROCEDURE:

CAUTION: Make sure that there are no open flames in the area when mixing flame fuels. NO SMOKING!

1. With Commercial Rubber Latex:

a. Place 7 parts by volume of latex and 92 parts by volume of gasoline in bottle. Cap bottle and shake to mix well.

b. Add 1 part by volume vinegar (or other acid) and shake until gel forms.

CAUTION: Concentrated acids will burn skin and destroy clothing. If any is spilled, wash away immediately with large quantities of water.

100

2. With Natural Latex:

a. Natural latex should form lumps as it comes from the plant. If lumps do not form, add a small amount of acid to the latex.

b. Strain off the latex lumps and allow to dry in air.

c. Place 20 parts by volume of latex in bottle and add 80 parts by volume of gasoline. Cover bottle and allow to stand until a swollen gel mass is obtained (2 to 3 days).

101 Section V
No. 4.6
GELLED FLAME FUELS

WAX SYSTEMS

Any of several common waxes can be used to gel gasoline for use as a flame fuel which will adhere to target surfaces.

30	Animal blood Serum	Food Medicine	Slaughter House Natural habitat

Any one of the following:

2	Salt	Food Industrial processes	Sea Water Natural brine Food store
	Ground Coffee	Food Caffeine source Beverage	Coffee plant Food store
	Dried Tea Leaves	Food Beverage	Tea plant Food store
	Sugar	Sweetening foods Industrial processes	Sugar cane Food store
	Lime	Mortar Plaster Medicine Ceramics Steel making Industrial processes	From calcium carbonate Hardware store Drug store Garden supply store
	Baking soda	Baking Beverages Medicine Industrial processes	Food store Drug store
	Epsom salts	Medicine Mineral water Industrial processes	Drug store Natural deposits Food store

MATERIALS REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
80	Gasoline	Motor fuel Solvent	Gas station Motor vehicles

Any one of the following:

20	Ozocerite Mineral wax Fossil wax Ceresin wax	Leather polish Sealing wax Candles Crayons Waxed paper Textile sizing	Natural deposits General stores Department store
	Beeswax	Furniture and floor waxes Artificial fruit and flowers Lithographing Wax paper Textile finish Candles	Honeycomb of bee General store Department store
	Bayberry wax Myrtle wax	Candles Soaps Leather polish Medicine	Natural form Myrica berries General store Department store Drug store

PROCEDURE:

1. Obtaining wax from Natural Sources: Plants and berries are potential sources of natural waxes. Place the plants and/or berries in boiling water. The natural waxes will melt.

Let the water cool. The natural waxes will form a solid layer on the water surface. Skim off the solid wax and let it dry. With natural waxes which have suspended matter when melted, screen the wax through a cloth.

2. Melt the wax and pour into jar or bottle which has been placed in a hot water bath.

3. Add gasoline to the bottle.

4. When wax has completely dissolved in the gasoline, allow the water bath to cool slowly to room temperature.

NOTE: If a gel does not form, add additional wax (up to 40% by volume) and repeat the above steps. If no gel forms with 40% wax, make a Lye solution by dissolving a small amount of Lye (Sodium Hydroxide) in an equal amount of water. Add this solution (1/2% by volume) to the gasoline wax mix and shake bottle until a gel forms.

GELLED FLAME FUELS

ANIMAL BLOOD SYSTEMS

Animal blood can be used to gel gasoline for use as a flame fuel which will adhere to target surfaces.

MATERIAL REQUIRED:

Parts by Volume	Ingredient	How Used	Common Source
68	Gasoline	Motor fuel Solvent	Gas station Motor vehicles

PROCEDURE:

1. Preparation of animal blood serum:

a. Slit animal's throat by jugular vein. Hang up-side down to drain.

b. Place coagulated (lumpy) blood in a cloth or on a screen and catch the red fluid (serum) which drains through.

c. Store in cool place if possible.

CAUTION: Do not get aged animal blood or the serum into an open cut. This can cause infections.

2. Pour blood serum into jar, bottle, or other container and add gasoline.

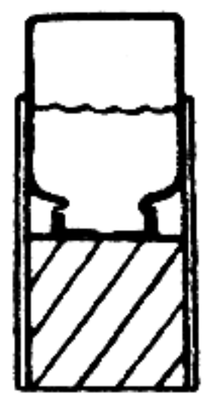
3. Add the salt (or other additive) to the mixture and stir until a gel forms.

ACID DELAY INCENDIARY

This device will ignite automatically after a given time delay.

MATERIAL REQUIRED:

Small jar with cap
Cardboard
Adhesive tape
Potassium Chlorate
Sugar
Sulphuric Acid (Battery Acid)
Rubber sheeting (automotive inner tube)



PROCEDURE:

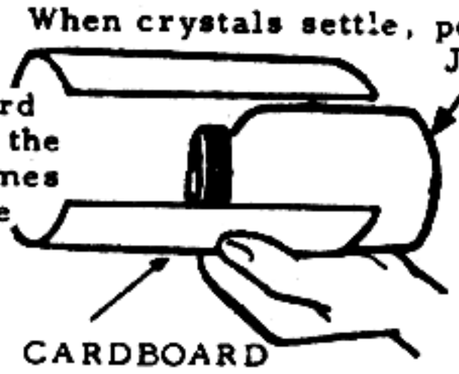
1. Sulphuric acid must be concentrated. If battery acid or other dilute acid is used, concentrate it by boiling. Container used should be of enamelware or oven glass. When dense white fumes begin to appear, immediately remove the acid from heat and allow to cool to room temperature.

CAUTION: Sulphuric acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Fumes are also dangerous and should not be inhaled.

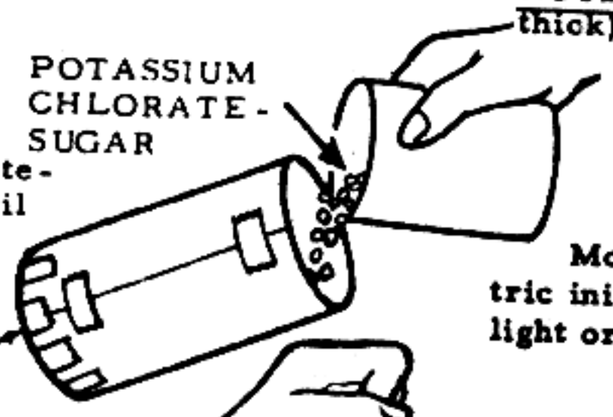
2. Dissolve one part by volume of Potassium Chlorate and one part by volume of sugar in two parts by volume of boiling water.

3. Allow the solution to cool. When crystals settle, pour off and discard the liquid.

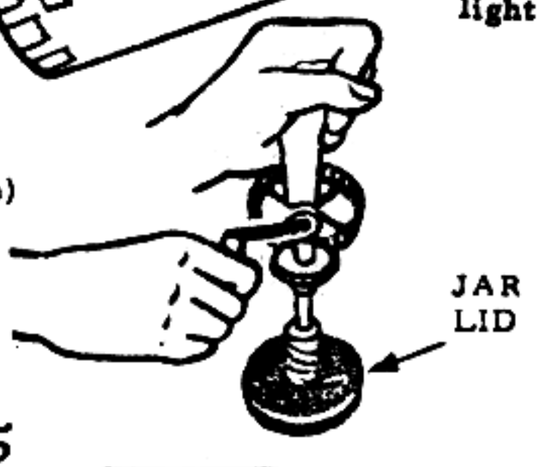
4. Form a tube from cardboard just large enough to fit around the outside of the jar and 2 to 3 times the height of the jar. Tape one end of the tube closed.



5. Pour wet Potassium Chlorate-sugar crystals into the tube until it is about 2/3 full. Stand the tube aside to dry.



6. Drill a hole through the cap of the jar about 1/2 inch (1 1/4 cm) in diameter.



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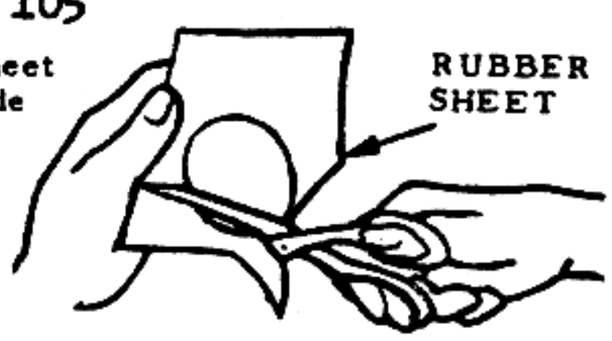
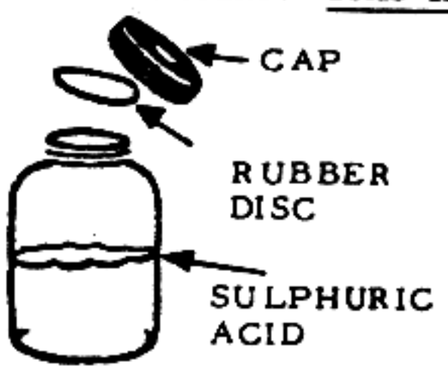
7. Cut a disc from rubber sheet so that it just fits snugly inside the lid of the jar.



8. Partly fill jar with water, cover with rubber disc and cap tightly with the drilled lid. Invert bottle and allow to stand for a few minutes to make sure that there are no leaks. THIS IS EXTREMELY IMPORTANT.

9. Pour water from jar and fill about 1/3 full with concentrated sulphuric acid. Replace the rubber disc and cap tightly.

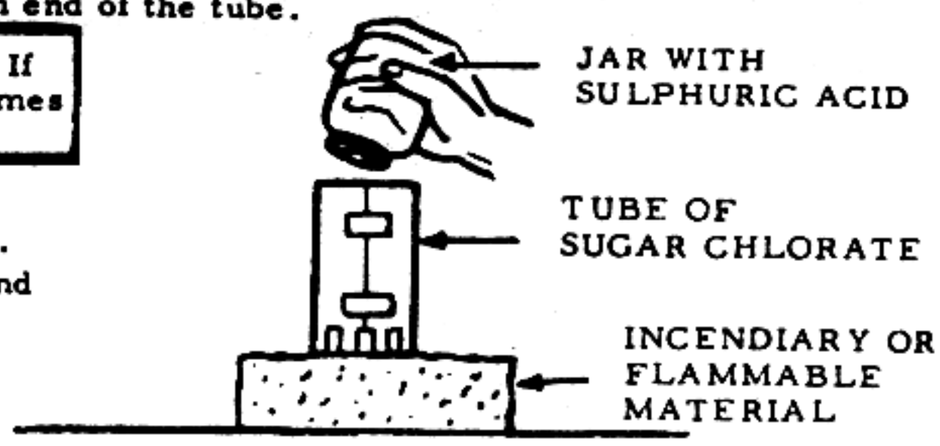


IMPORTANT: Wash outside of jar thoroughly with clear water. If this is not done, the jar may be dangerous to handle during use.

HOW TO USE:

1. Place the tube containing the Sugar Chlorate crystals on an incendiary or flammable material taped end down.

2. Turn the jar of sulphuric acid cap end down and slide it into the open end of the tube.

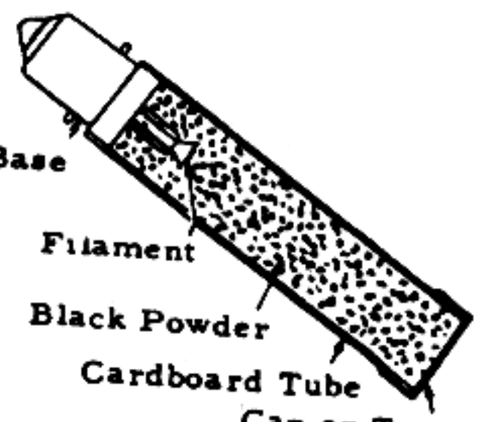


After a time delay, the acid will eat through the rubber disc and ignite the sugar chlorate mix. The delay time depends upon the thickness and type of rubber used for the disc. Before using this device, tests should be conducte determine the delay time that can be expected.

NOTE: A piece of standard automobile inner tube (about 1/32" thick) will provide a delay time of approximately 45 minutes.

Section VI
106 No. 1
ELECTRIC BULB INITIATOR

Mortars, mines and similar weapons often make use of electric initiators. An electric initiator can be made using a flashlight or automobile electric light bulb.



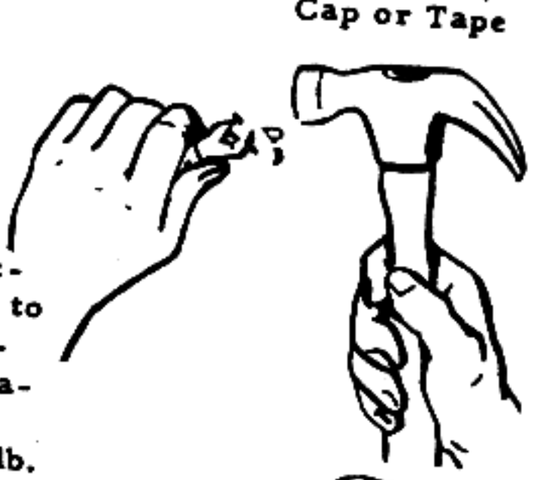
MATERIAL REQUIRED

Electric light bulb and mating socket
Cardboard or heavy paper
Black Powder
Adhesive tape

PROCEDURE

Method I

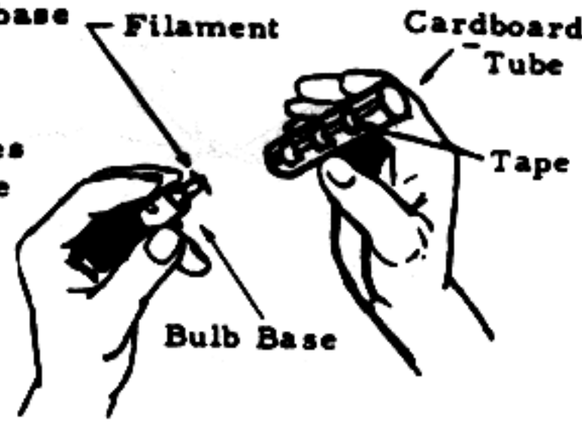
1. Break the glass of the electric light bulb. Take care not to damage the filament. The initiator will NOT work if the filament is broken. Remove all glass above the base of the bulb.



2. Form a tube 3 to 4 inches long from cardboard or heavy paper to fit around the base of the bulb. Join the tube with adhesive tape.

3. Fit the tube to the bulb base and tape in place.

Make sure that the tube does not cover that portion of the bulb base that fits into the socket.



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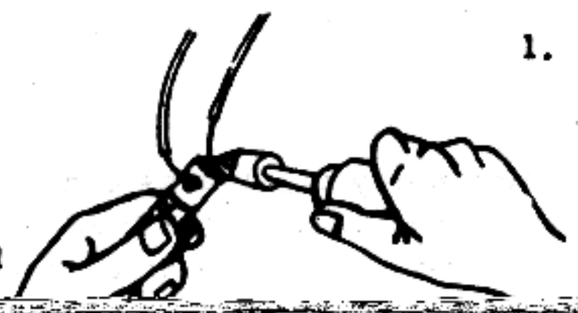
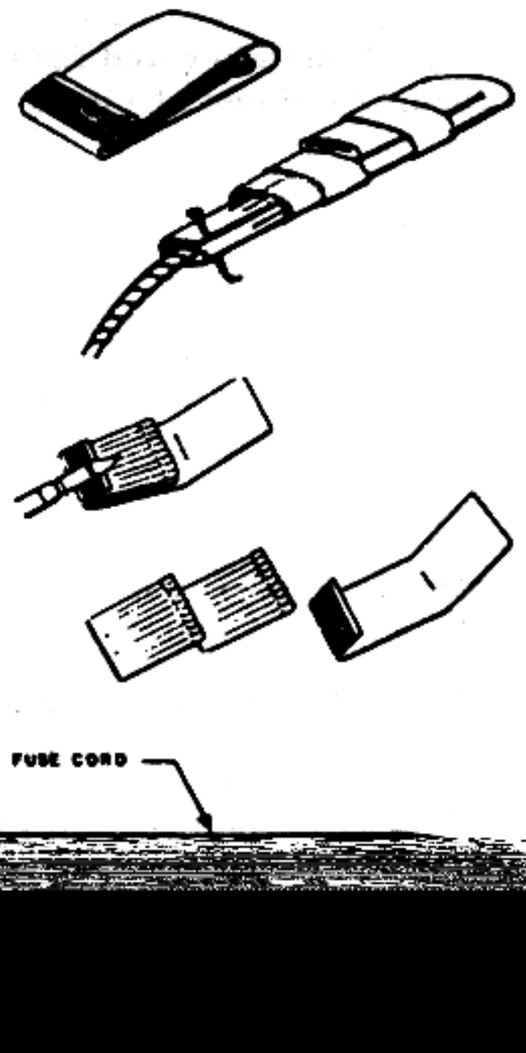
4. If no socket is available for connecting the initiator to the firing circuit, solder the connecting wires to the bulb base.

CAUTION: Do NOT use a hot soldering iron on the completed



Material Required

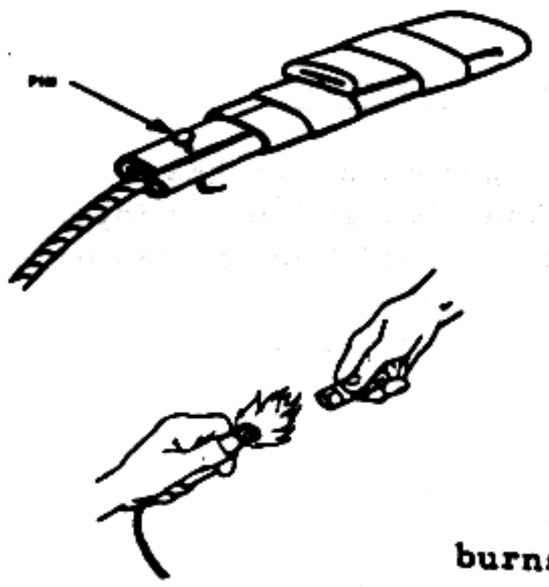
Paper book matches.
Adhesive or friction tape.
Fuse cord (improvised or commercial).
Pin or small nail.



Procedure

1. **Remove the staple(s) from match book and separate matches from cover.**

8. Push pin or small nail through matches and fuse cord. Bend end of pin or nail.



Method of Use

To light the fuse cord, the igniter is held by both hands and pulled sharply or quickly.

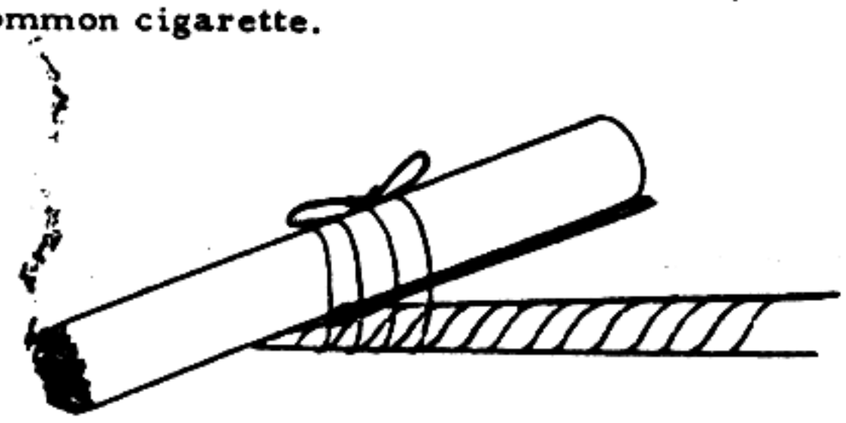
CAUTION

Store matches and completed fuse igniters in moistureproof containers such as plastic or rubber type bags until ready for use. Damp or wet paper book matches will not ignite. Fuse lengths should not exceed 12 in. (30 cm) for easy storage. These can be spliced to main fuses when needed.

Section VI

110 No. 3
DELAY IGNITER FROM CIGARETTE

A simple and economical time delay can be made with a common cigarette.

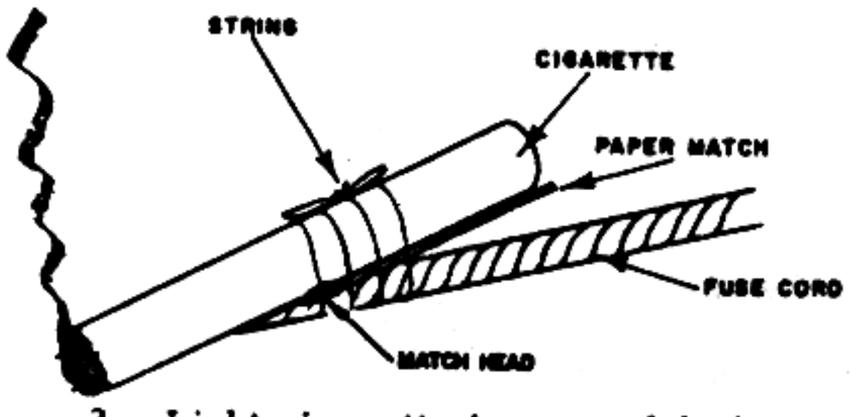


Materials Required

Cigarette.
Paper match.
String (shoelace or similar cord).
Fuse cord (improvised or commercial).

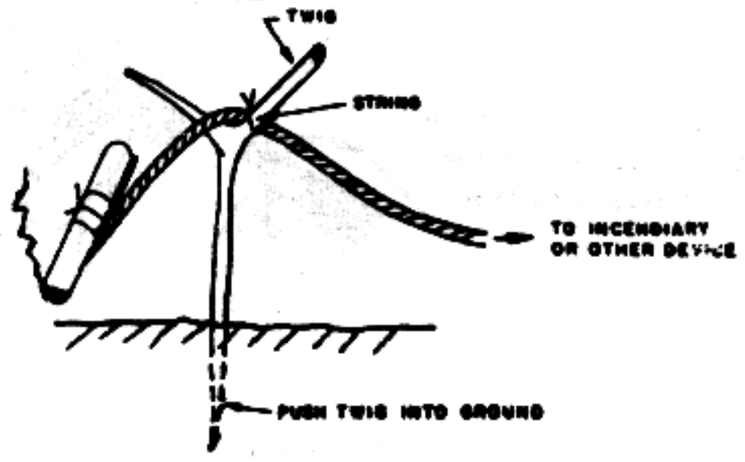
Procedure

1. Cut end of fuse cord to expose inner core.



2. Light cigarette in normal fashion. Place a paper match so that the head is over exposed end of fuse cord and tie both to the side of the burning cigarette with string.

111



3. Position the burning cigarette with fuse so that it burns freely. A suggested method is to hang the delay on a twig.

NOTE

Common dry cigarettes burn about 1 inch every 7 or 8 minutes in still air. If the fuse cord is placed 1 inch from the burning end of a cigarette a time delay of 7 or 8 minutes will result.

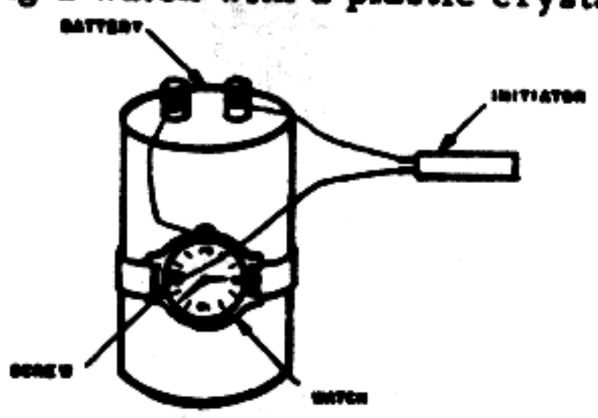
Delay time will vary depending upon type of cigarette, wind, moisture, and other atmospheric conditions.

To obtain accurate delay time, a test run should be made under "use" conditions.

Section VI

112 No. 4
WATCH DELAY TIMER

A time delay device for use with electrical firing circuits can be made by using a watch with a plastic crystal.



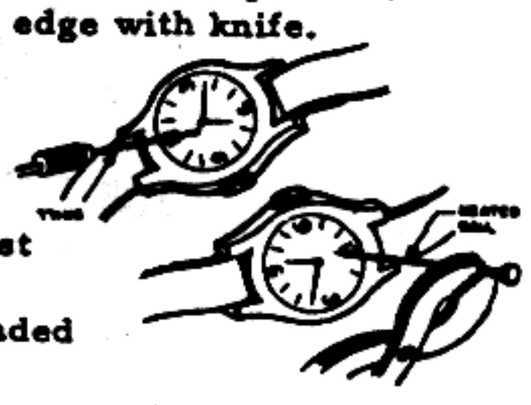
Material and Equipment Required

Watch with plastic crystal.
Small clean metal screw.
Battery.
Connecting wires.
Drill or nail.

Procedure

1. If watch has a sweep or large second hand, remove it. If delay time of more than one hour is required, also remove the minute hand. If hands are painted, carefully scrape paint from contact edge with knife.

2. Drill a hole through the crystal of the watch or pierce the crystal with a heated nail. The hole must be small enough that the screw can be tightly threaded into it.



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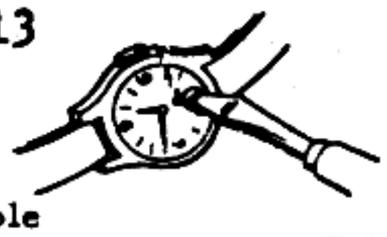


3. Place the screw in the hole and turn down as far as possible without making contact with the face of the watch. If screw has a pointed tip, it may be necessary to grind the tip flat.

If no screw is available, pass a bent stiff wire through the hole and tape to the crystal.

IMPORTANT:	Check to make sure hand of watch cannot pass screw or wire without contacting it.

How to Use

1. Set the watch so that a hand will reach the screw or wire at the time you want the firing circuit completed.

2. Wind the watch.

3. Attach a wire from the case of the watch to one terminal of the battery.

4. Attach one wire from an electric initiator (blasting cap, squib, or alarm device) to the screw or wire on the face of the watch.

5. After thorough inspection is made to assure that the screw or the wire connected to it is not touching the face or case of the watch, attach the other wire from the initiator to the second terminal of the battery.

CAUTION
Follow step 5 carefully to prevent premature initiation.

Section VI

114 No. 5

NO-FLASH FUSE IGNITER

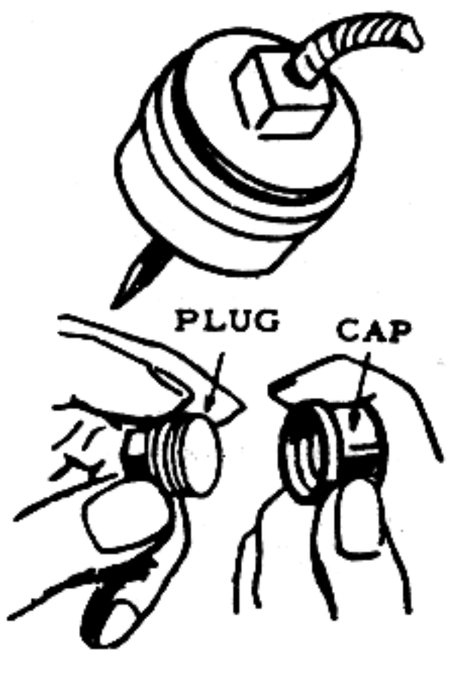
A simple no-flash fuse igniter can be made from common pipe fittings.

MATERIAL REQUIRED:

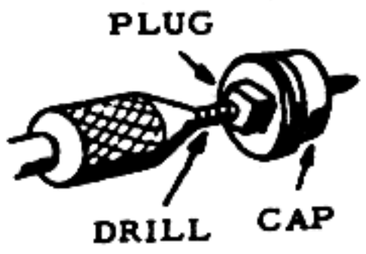
1/4 in. (6mm) Pipe Cap
Solid 1/4 in. (6mm) Pipe Plug
Flat head nail about 1/16 in. (1 1/2 mm) in diameter
Hand Drill
Common "Strike Anywhere" Matches
Adhesive Tape

PROCEDURE:

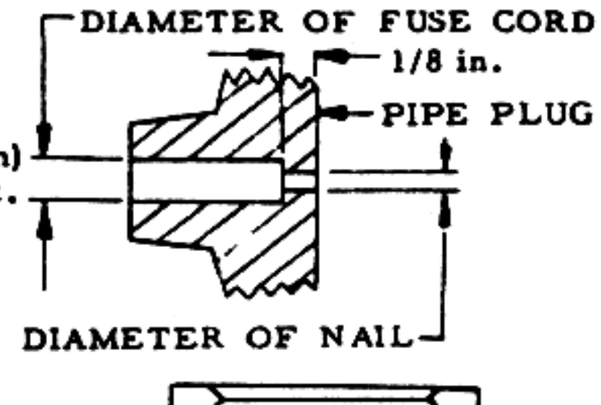
1. Screw the pipe plug tightly into the pipe cap.



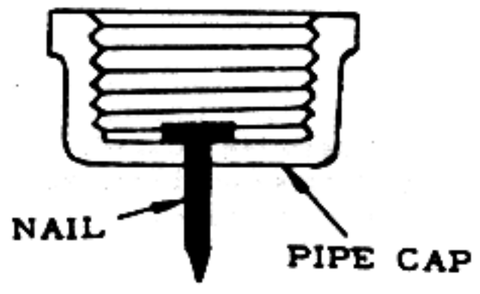
2. Drill hole completely through the center of the plug and cap large enough that the nail fits loosely.



3. Enlarge the hole in the plug except for the last 1/8 in. (3 mm) so that the fuse cord will just fit.



4. Remove the plug from the cap and push the flat head nail through the hole in the cap from the inside.



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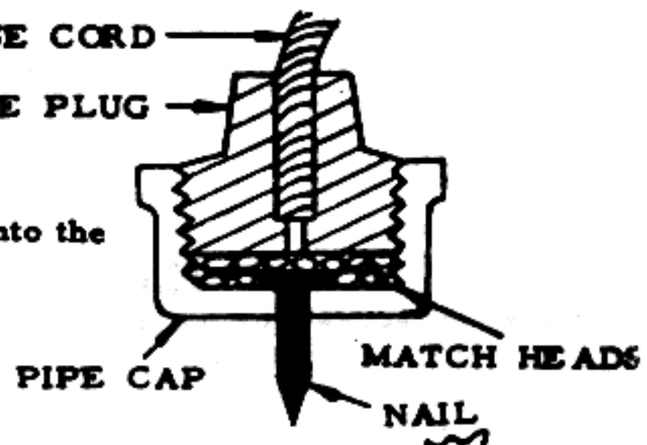
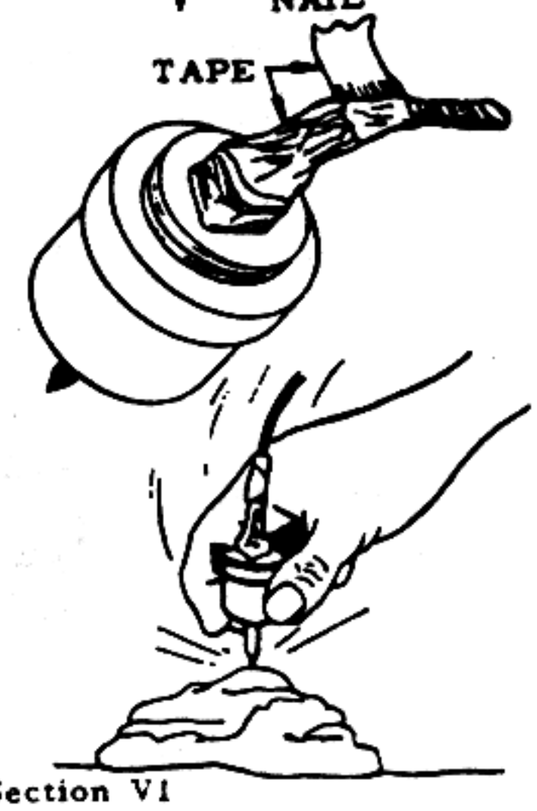
5. Cut the striking tips from approximately 10 strike-anywhere matches. Place match tips inside pipe cap and screw plug in finger tight.

HOW TO USE:

1. Slide the fuse cord into the hole in the pipe plug.



2. Tape igniter to fuse cord.



3. Tap point of nail on a hard surface to ignite the fuse.

Section VI

116 No. 6

DRIED SEED TIMER

A time delay device for electrical firing circuits can be made using the principle of expansion of dried seeds.

MATERIEL REQUIRED:

Dried peas, beans or other dehydrated seeds

Wide mouth glass jar with non-metal cap
Two screws or bolts
Thin metal plate
Hand drill
Screwdriver

PROCEDURE:

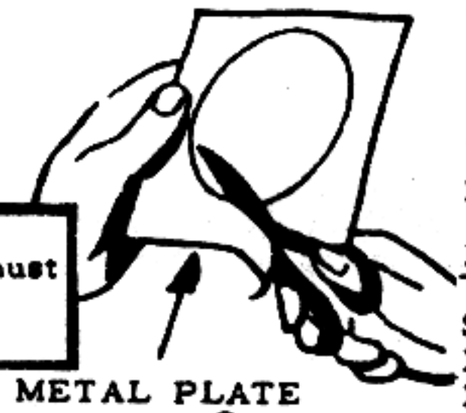
1. Determine the rate of rise of the dried seeds selected. This is necessary to determine delay time of the timer.

   a. Place a sample of the dried seeds in the jar and cover with water.

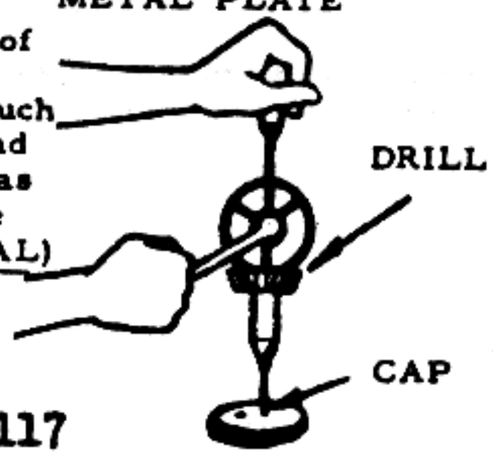
   b. Measure the time it takes for the seeds to rise a given height. Most dried seeds increase 50% in one to two hours.

2. Cut a disc from thin metal plate. Disc should fit loosely inside the jar.

NOTE: If metal is painted, rusty or otherwise coated, it must be scraped or sanded to obtain a clean metal surface.



3. Drill two holes in the cap of the jar about 2 inches apart. Diameter of holes should be such that screws or bolts will thread tightly into them. If the jar has a metal cap or no cap, a piece of wood or plastic (NOT METAL) can be used as a cover.



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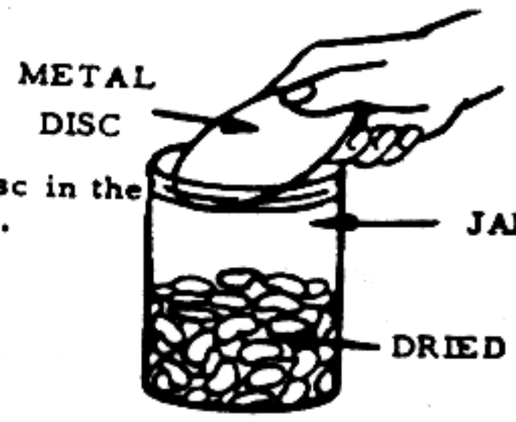
4. Turn the two screws or bolts through the holes in the cap. Bolts should extend about one in. (2 1/2 cm) into the jar.

IMPORTANT: Both bolts must extend the same distance below the container cover.

5. Pour dried seeds into the container. The level will depend upon the previously measured rise time and the desired delay.

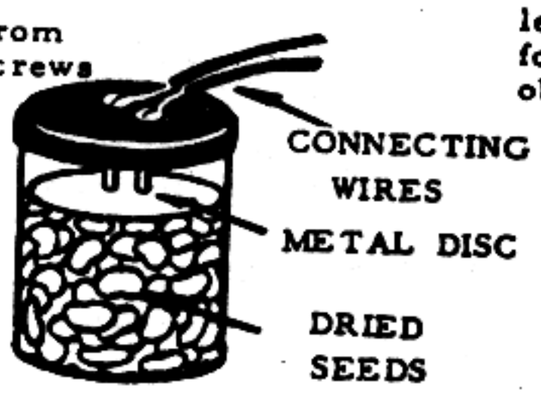


6. Place the metal disc in the jar on top of the seeds.

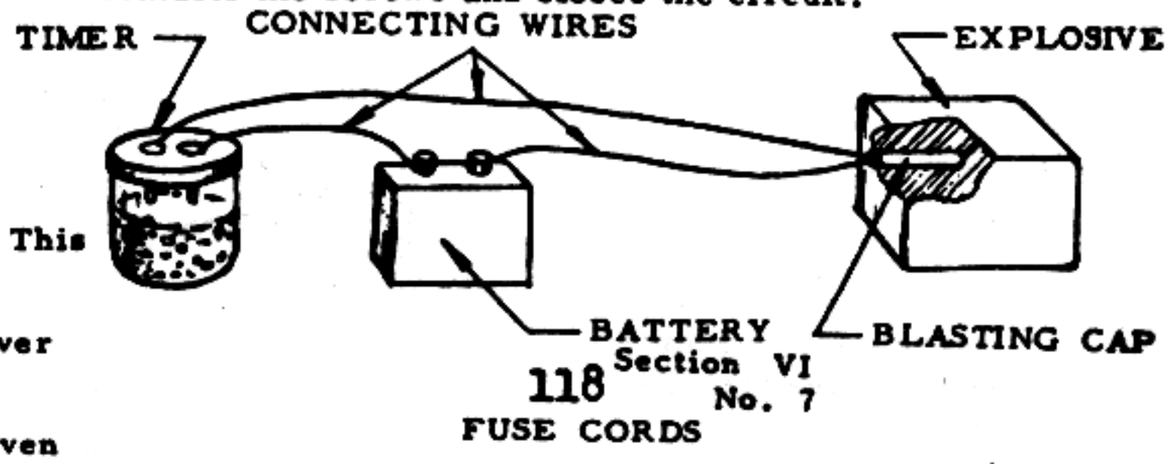
HOW TO USE:

1. Add just enough water to completely cover the seeds and place the cap on the jar.

2. Attach connecting wires from the firing circuit to the two screws on the cap.



Expansion of the seeds will raise the metal disc until it contacts the screws and closes the circuit.



118 Section VI No. 7

FUSE CORDS

These fuse cords are used for igniting propellants and incendiaries or, with a non-electric blasting cap, to detonate explosives.

FAST BURNING FUSE

The burning rate of this fuse is approximately 40 in. (100 cm) per minute.

MATERIAL REQUIRED:

Soft Cotton String
Fine Black Powder --or-
Piece of round stick
Two pans or dishes

- Potassium Nitrate (Saltpeter) 25 parts
- Charcoal 3 parts
- Sulphur 2 parts

PROCEDURE:

1. Moisten fine Black Powder to form a paste or prepare a substitute as follows:

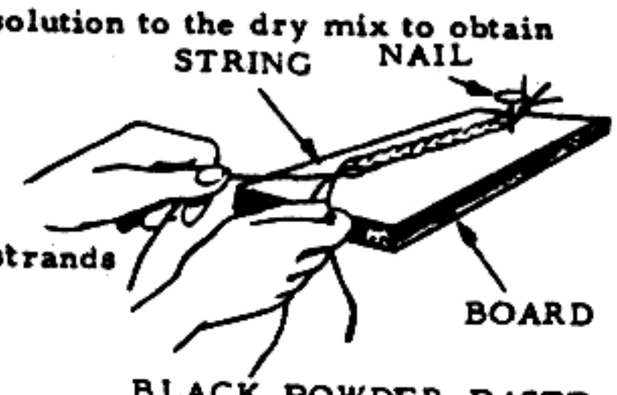
   a. Dissolve Potassium Nitrate in an equal amount of water.

   b. Pulverize charcoal by spreading thinly on a hard surface and rolling the round stick over it to crush to a fine powder.

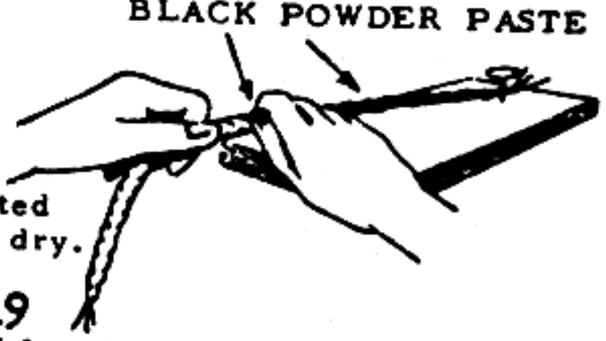
   c. Pulverize sulphur in the same manner.

   d. Dry mix sulphur and charcoal.

   e. Add Potassium Nitrate solution to the dry mix to obtain a thoroughly wet paste.



2. Twist or braid three strands of cotton string together.



3. Rub paste mixture into twisted string with fingers and allow to dry.

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4. Check actual burning rate of fuse by measuring the time it takes for a known length to burn. This is used to determine the length needed for a desired delay time. If 5 in. (12 1/2 cm) burns for 6 seconds, 50 in. (125 cm) of fuse cord will be needed to obtain a one minute (60 second) delay time.

SLOW BURNING FUSE

The burning rate of this fuse is approximately 2 in. (5 cm) per minute.

MATERIAL REQUIRED:

Cotton String or 3 Shoelaces
Potassium Nitrate or Potassium Chlorate
Granulated Sugar

PROCEDURE:

1. Wash cotton string or shoelaces in hot soapy water; rinse in fresh water.

2. Dissolve 1 part Potassium Nitrate or Potassium Chlorate and 1 part granulated sugar in 2 parts hot water.

3. Soak string or shoelaces in solution.

4. Twist or braid three strands of string together and allow to dry.

5. Check actual burning rate of the fuse by measuring the time it takes for a known length to burn. This is used to determine the length needed for the desired delay time. If 2 in. (5 cm) burns for 1 minute, 10 in. (25 cm) will be needed to obtain a 5 minute delay.

NOTE: The last few inches of this cord (the end inserted in the material to be ignited) should be coated with the fast burning Black Powder paste if possible. This must be done when the fuse is used to ignite a blasting cap.

REMEMBER: The burning rate of either of these fuses can vary greatly. Do Not Use for ignition until you have checked their burning rate.

120 Section VI No. 8
CLOTHESPIN TIME DELAY SWITCH

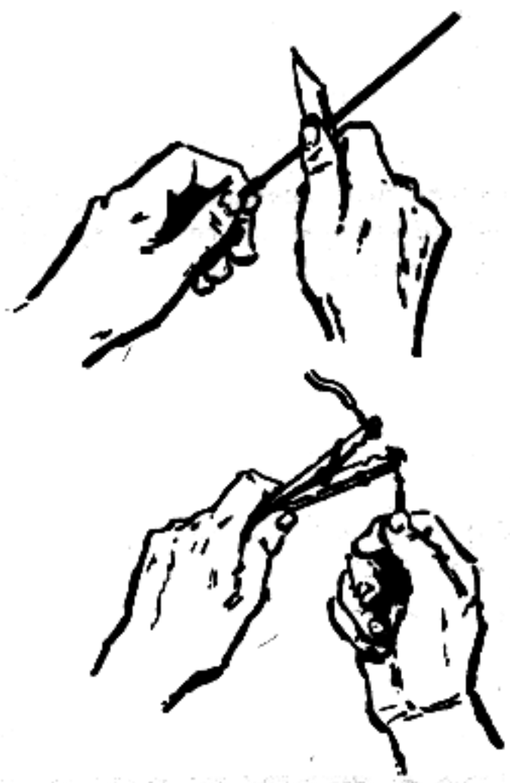
A 3 to 5 minute time delay switch can be made from the clothespin switch (Section VII, No. 1) and a cigarette. The system can be used for initiation of explosive charges, mines, and booby traps.

MATERIAL REQUIRED:

Spring type clothespin
Solid or stranded copper wire about 1/16 in. (2 mm) in diameter (field or bell wire is suitable)
Fine string, about 6 inches in length
Cigarette
Knife

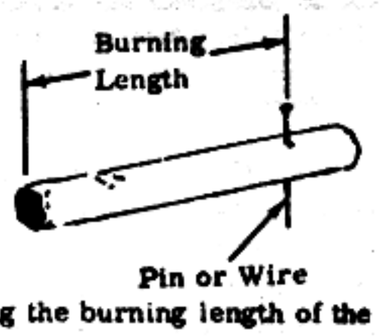
PROCEDURE:

1. Strip about 4 inches (10 cm) of insulation from the ends of 2 copper wires. Scrape copper wires with pocket knife until metal is shiny.

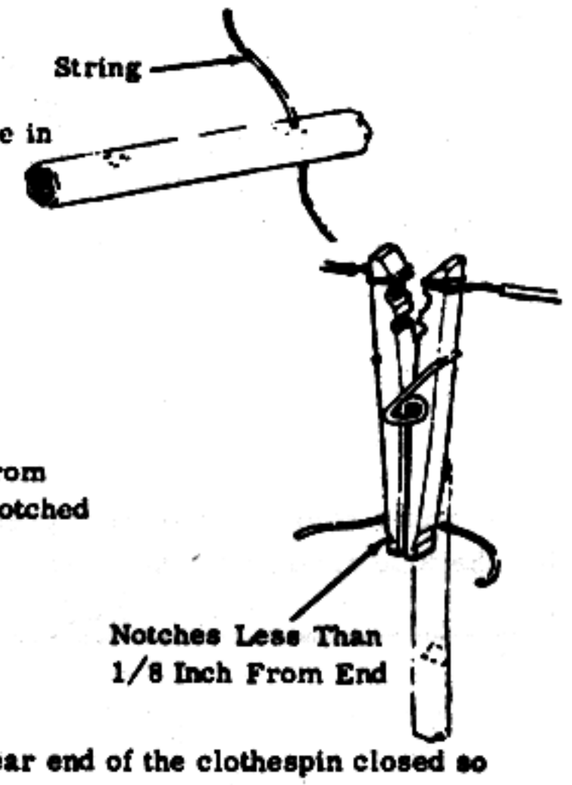


2. Wind one scraped wire tightly on one jaw of the clothespin, and the other wire on the other jaw so that the wires will be in contact with each other when the jaws are closed.

3. Measuring from tip of cigarette, measure a length of cigarette that will correspond to the desired delay time. Make a hole in cigarette at this point, using wire or pin.



4. Thread string through hole in cigarette.

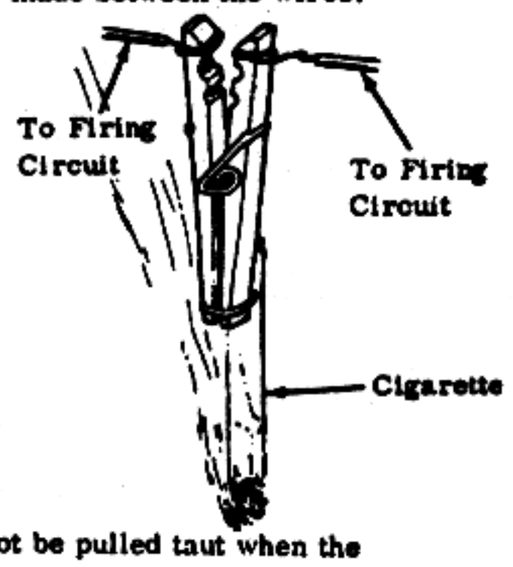


5. Tie string around rear of clothespin, 1/8 inch or less from end. The clothespin may be notched to hold the string in place.

NOTE: The string must keep the rear end of the clothespin closed so that the jaws stay open and no contact is made between the wires.

HOW TO USE:

Suspend the entire system vertically with the cigarette tip down. Light tip of cigarette. Switch will close and initiation will occur when the cigarette burns up to and through the string.



NOTE: Wires to the firing circuit must not be pulled taut when the switch is mounted. This could prevent the jaws from closing.

NOTE: Delay time may be adjusted by varying the burning length of the cigarette. Burning rate in still air is approximately 7 minutes per inch (2.5 cm). Since this rate varies with environment and brand of cigarette, it should be tested in each case if accurate delay time is desired.

SECTION VI
122 No. 9
TIME DELAY GRENADE

This delay mechanism makes it possible to use an ordinary grenade as a time bomb.

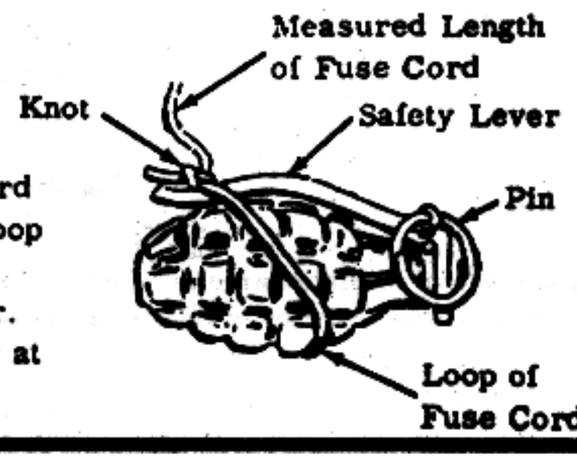
MATERIAL REQUIRED:

Grenade
Fuse Cord

IMPORTANT: Fuse cord must be the type that burns completely. Fast burning improvised fuse cord (Section VI, No. 7) is suitable. Safety fuse is not satisfactory, since its outer covering does not burn.

PROCEDURE:

1. Bend end of safety lever upward to form a hook. Make a single loop of fuse cord around the center of the grenade body and safety lever. Tie a knot of the non-slip variety at the safety lever.



NOTE: The loop must be tight enough to hold the safety lever in position when the pin is removed.

2. Measuring from the knot along the free length of the fuse cord, measure off a length of fuse cord that will give the desired delay time. Cut off the excess fuse cord.

HOW TO USE:

1. Place hand around grenade and safety lever so safety lever is held in place. Carefully remove pin.

2. Emplace grenade in desired location while holding grenade and safety lever.

3. Very carefully remove hand from grenade and safety lever, making sure that the fuse cord holds the safety lever in place.

123

CAUTION: If loop and knot of fuse cord do not hold for any reason and the safety lever is released, the grenade will explode after the regular delay time.

4. Light free end of fuse cord.

Section VI
124 No. 10
CAN-LIQUID TIME DELAY

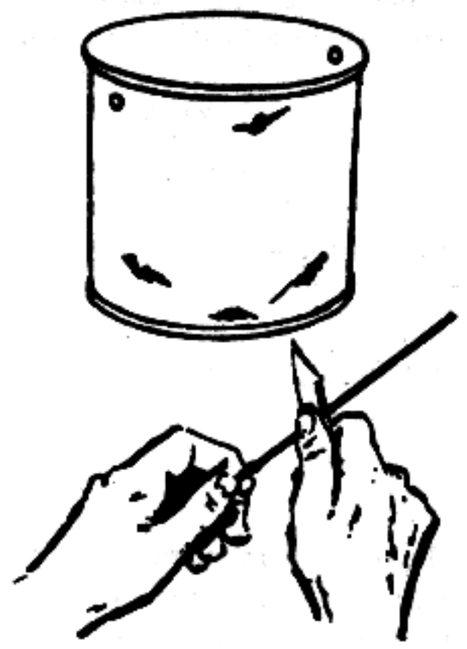
A time delay device for electrical firing circuits can be made using a can and liquid.

MATERIAL REQUIRED:

Can
Liquid (water, gasoline, etc.)
Small block of wood or any material that will float on the liquid used
Knife
2 pieces of solid wire, each piece 1 foot (30 cm) or longer

PROCEDURE:

1. Make 2 small holes at opposite sides of the can very close to the top.



2. Remove insulation from a long piece of wire for a distance a little greater than the diameter of the can.

3. Secure the wire in place across the top of the can by threading it through the holes and twisting in place, leaving some slack. Make loop in center or wire. Be sure a long piece of wire extends from one end of the can.

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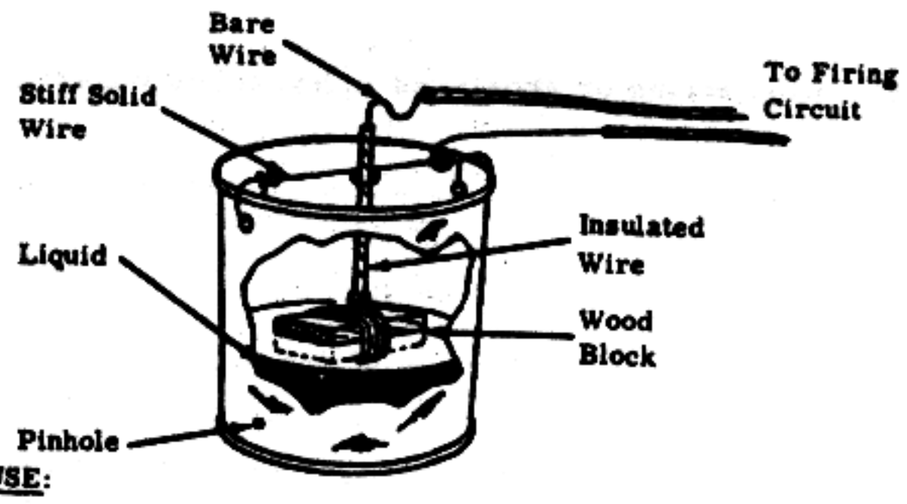
4. Wrap a piece of insulated wire around the block of wood. Scrape insulation from a small section of this wire and bend as shown so that wire contacts loop before wood touches bottom of container. Thread this wire through the loop of bare wire.

5. Make a very small hole (pinhole) in the side of the container. Fill container with a quantity of liquid corresponding to the desired delay time. Since the rate at which liquid leaves the can depends upon weather conditions, liquid used, size of hole, amount of liquid in the container, etc., determine the delay time for each individual case. Delays from a few minutes to many hours are possible. Vary time by adjusting liquid level, type of liquid (water, oil) and hole size.



HOW TO USE:

1. Fill can with liquid to the same level as during experimental run (step 5 above). Be sure that wooden block floats on liquid and that wire is free to move down as liquid leaves container.

2. Connect wires to firing circuit.

NOTE: A long term delay can be obtained by placing a volatile liquid (gasoline, ether, etc.) in the can instead of water and relying on evaporation to lower the level. Be sure that the wood will float on the liquid used. DO NOT MAKE PINHOLE IN SIDE OF CAN!

Section VI
126 No. 11
SHORT TERM TIME DELAY FOR GRENADE

A simple modification can produce delays of approximately 12 seconds for grenades when fired from Grenade Launchers (Section IV, No. 5).

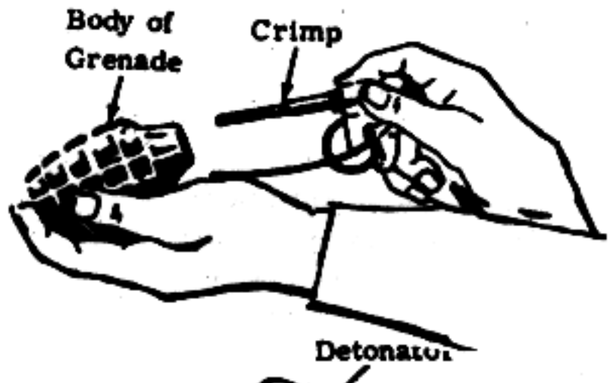
MATERIAL REQUIRED:

Grenade
Nail
Knife, Pliers } may not be needed
Safety fuse

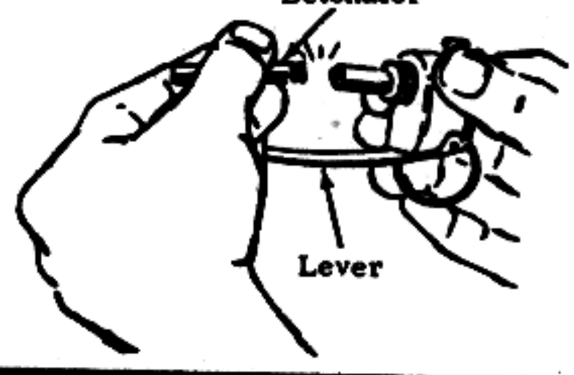
NOTE: Any safety or improvised fuse may be used. However, since different time delays will result, determine the burning rate of the fuse first.

PROCEDURE:

1. Unscrew fuse mechanism from body of grenade and remove. Pliers may have to be used.

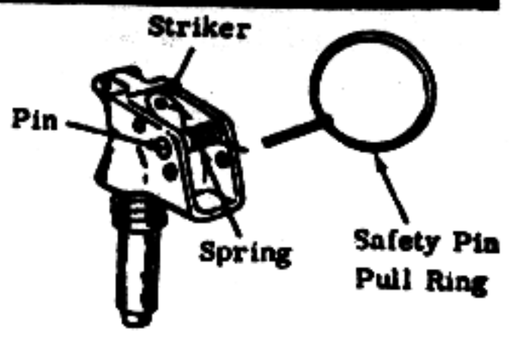


2. Carefully cut with knife or break off detonator at crimp and save for later use.



CAUTION: If detonator is cut or broken below the crimp, detonation may occur and severe injuries could result.

3. Remove safety pin pull ring and lever, letting striker hit the primer. Place fuse mechanism aside until delay fuse powder mix in mechanism is completely burned.



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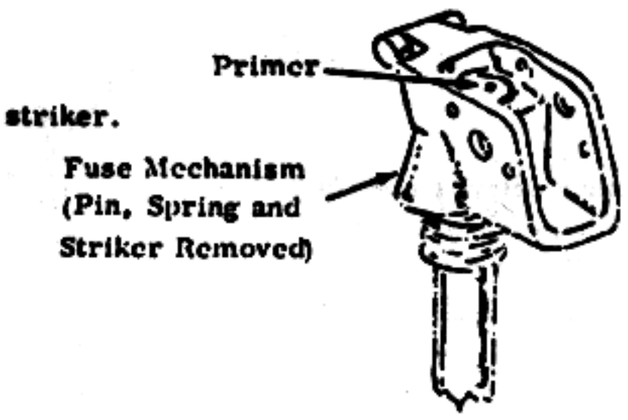
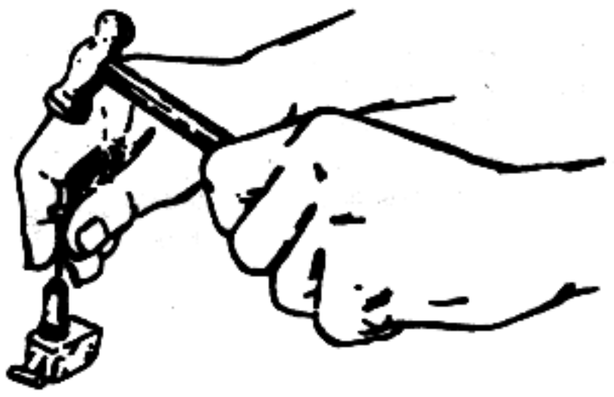
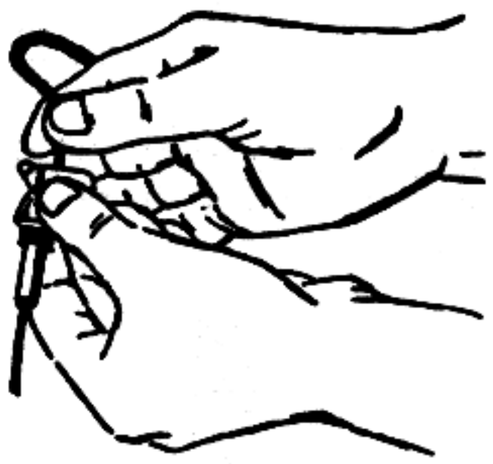


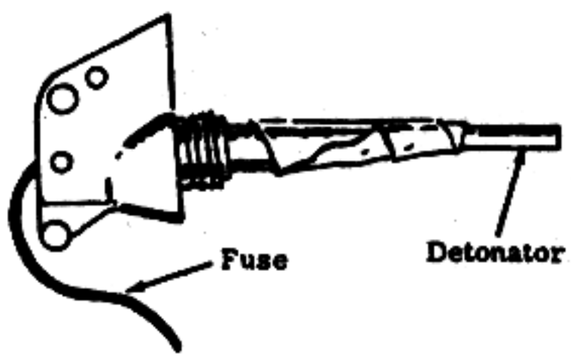
4. Remove pin, spring, and striker.



5. Remove primer from fuse mechanism by pushing nail through bottom end of primer hole and tapping with hammer.



6. Insert safety fuse through top of primer hole. Enlarge hole if necessary. The fuse should go completely through the hole.



7. Insert fuse into detonator and tape it securely to modified fuse mechanism.

NOTE: Be sure that fuse rests firmly against detonator at all times.

8. Screw modified fuse mechanism back into grenade. Grenade is now ready for use.

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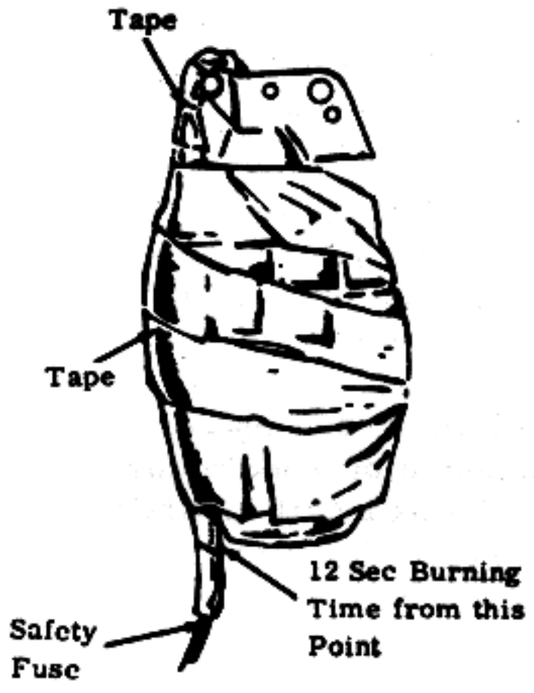
NOTE: If time delay is used for Improvised Grenade Launchers (Section IV, No. 5) -

1. Wrap tape around safety fuse.
2. Securely tape fuse to grenade.
3. Load grenade in launcher. Grenade will explode in approximately 12 seconds after safety fuse burns up to bottom of grenade.



129 Section VI
No. 12

LONG TERM TIME DELAY FOR GRENADE

A simple modification can produce delays of approximately 20 seconds for grenades when fired from Grenade Launchers (Section IV, No. 5).

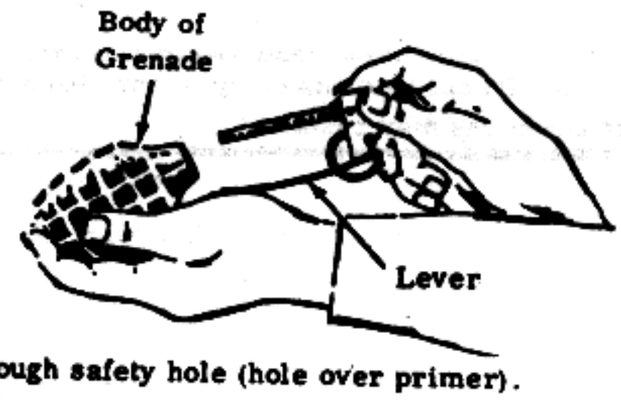
MATERIAL REQUIRED:

Grenade
Nail
"Strike-anywhere" matches, 6 to 8
Pliers (may not be needed)
Knife or sharp cutting edge
Piece of wood
Safety fuse

NOTE: Any safety or improvised fuse may be used. However, since different time delays will result, determine the burning rate of the fuse first.

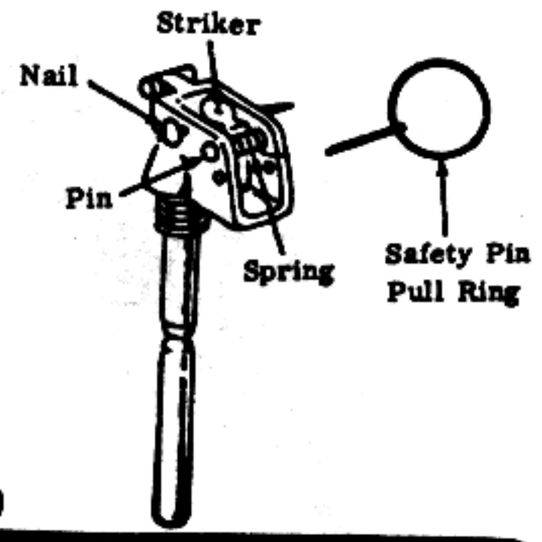
PROCEDURE:

1. Unscrew fuse mechanism from body of grenade and remove. Pliers may have to be used.



2. Insert nail completely through safety hole (hole over primer).

3. Carefully remove safety pin pull ring and lever, and allow striker to hit nail.



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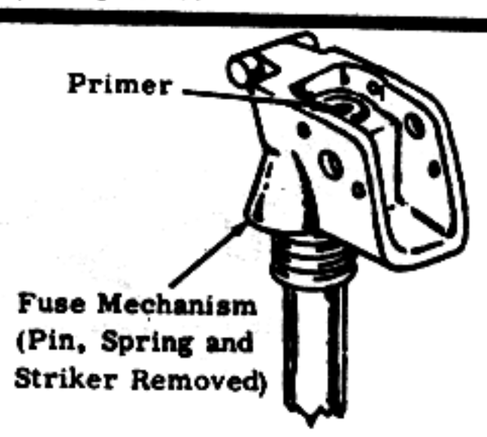
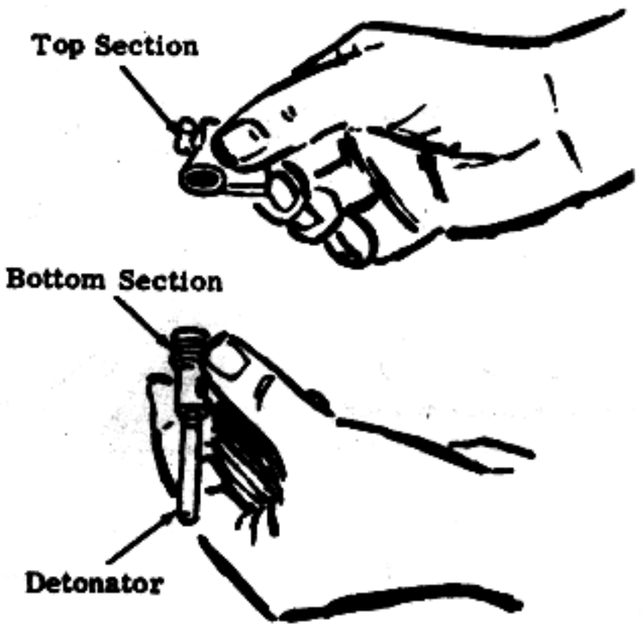
CAUTION: If for any reason, striker should hit primer instead of nail, detonator will explode after (4-5 sec.) delay time.

4. Push pin out and remove spring and striker. Remove nail.

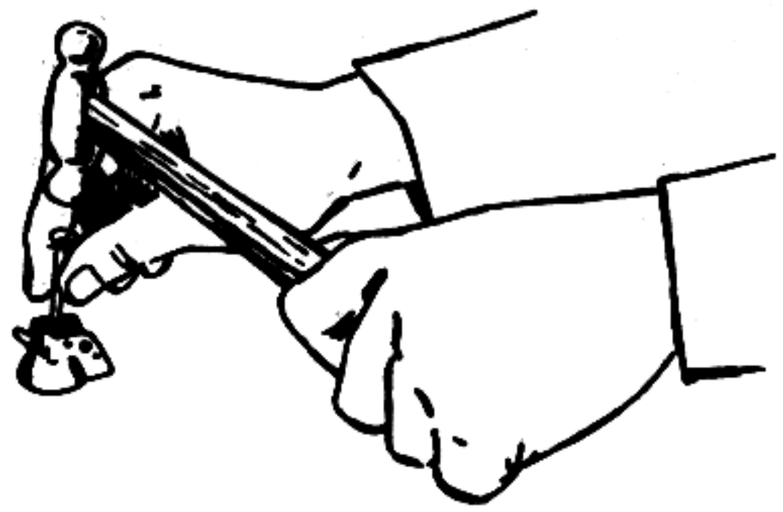


5. Carefully remove top section of fuse mechanism from bottom section by unscrewing. Pliers may have to be used.

CAUTION: Use extreme care - sudden shock may set off detonator.



6. Fire primer by hitting nail placed against top of it. Remove fired primer (same as procedure 5 of Section VI, No. 11).



CAUTION: Do not hold assembly in your hand during above operation, as serious burns may result.

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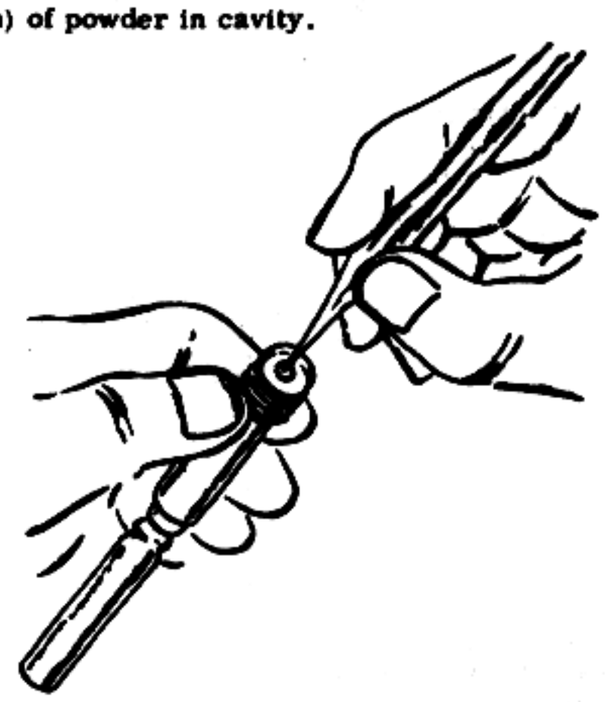
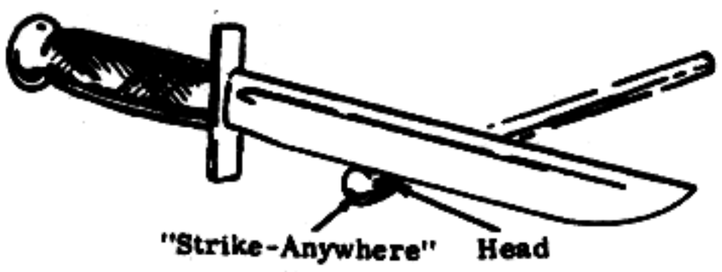
7. Scrape delay fuse powder with a sharpened stick. Loosen about 1/4 in. (6 mm) of powder in cavity.



8. Cut off tips (not whole head) of 6 "strike-anywhere" matches with sharp cutting edge. Drop them into delay fuse hole.

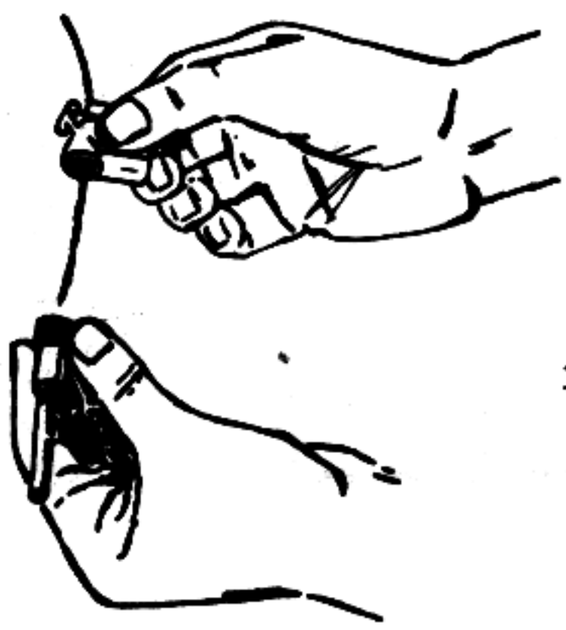


"Strike-Anywhere" Head Match Tip

9. Place safety fuse in delay fuse hole so that it is flush against the match tips.

IMPORTANT: Be sure fuse remains flush against the match tips at all times.

10. Thread fuse through primer hole. Enlarge hole if necessary. Screw modified fuse mechanism back together. Screw combination back into grenade. Grenade modification is now ready for use. Light fuse when ready to use.



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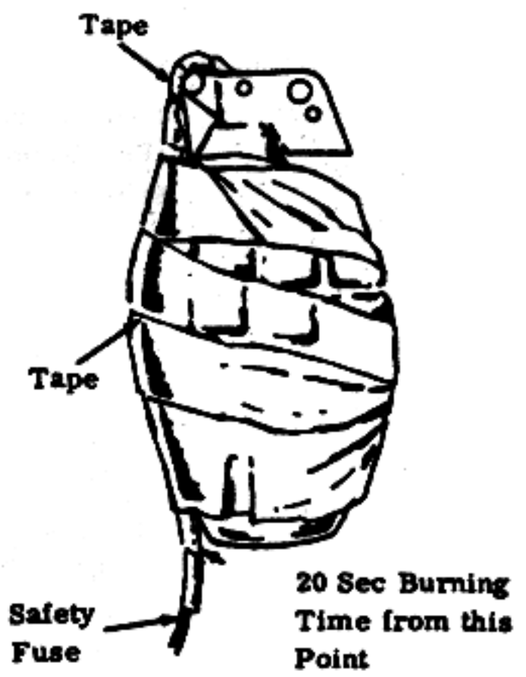
NOTE: If time delay is used for Improvised Grenade Launchers (Section IV, No. 5) -

1. Wrap tape around safety fuse.
2. Securely tape fuse to grenade
3. Load grenade in launcher. Grenade will explode in approximately 20 seconds after safety fuse burns up to bottom of grenade.

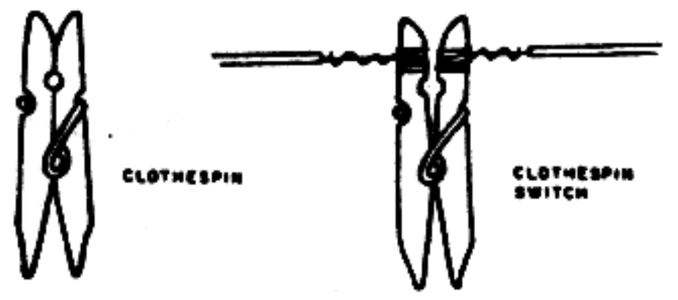


Section VII

133 No. 1

CLOTHESPIN SWITCH

A spring type clothespin is used to make a circuit closing switch to actuate explosive charges, mines, booby traps and alarm systems.

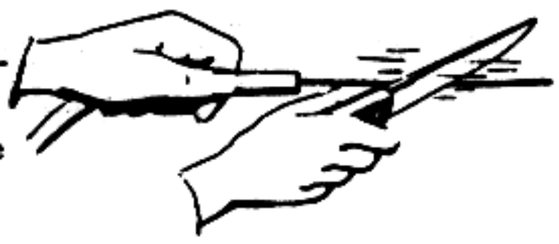


Material Required

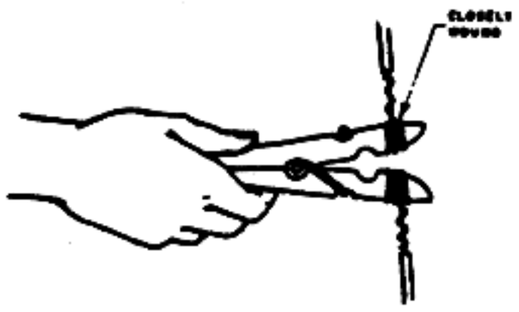
Spring type clothespin.
Solid copper wire -- 1/16 in. (2 mm) in diameter.
Strong string on wire.
Flat piece of wood (roughly 1/8 x 1" x 2").
Knife.

Procedure

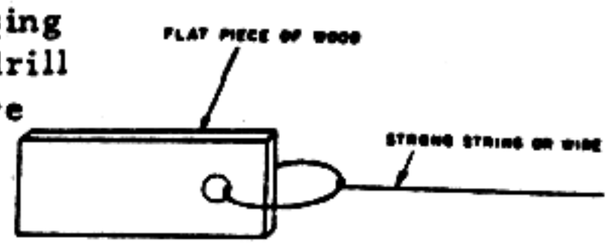
1. Strip four in. (10 cm) of insulation from the ends of 2 solid copper wires. Scrape copper wires with pocket knife until metal is shiny.



2. Wind one scraped wire tightly on one jaw of the clothespin, and the other wire on the other jaw.



3. Make a hole in one end of the flat piece of wood using a knife, heated nail or drill Tie strong string or wire through the hole.



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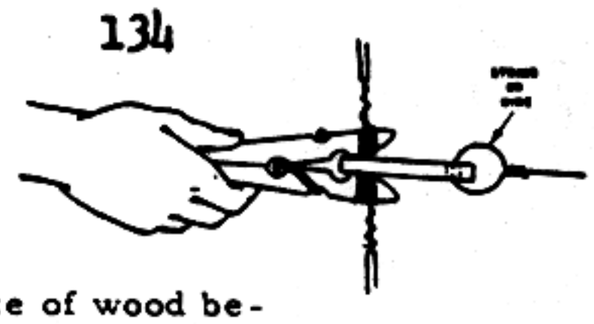
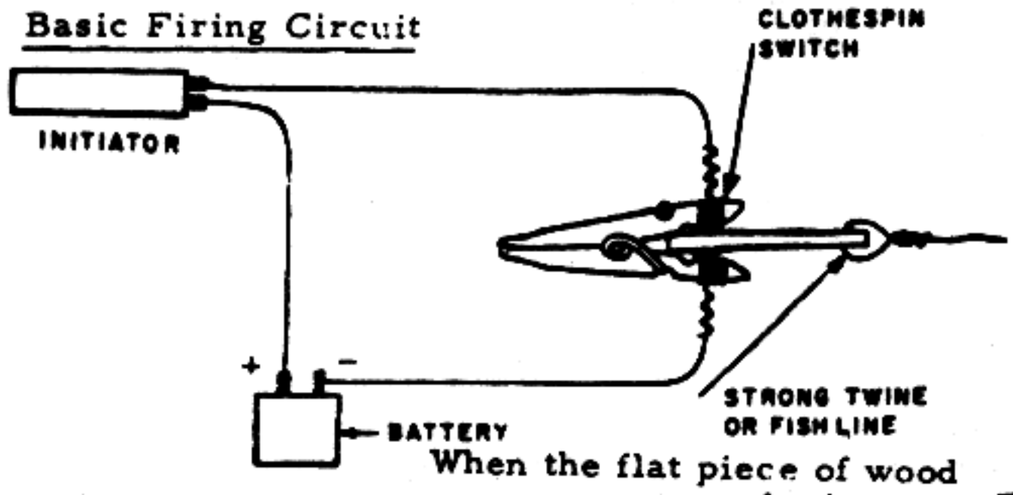


5. Place flat piece of wood between jaws of the clothespin switch.

Basic Firing Circuit

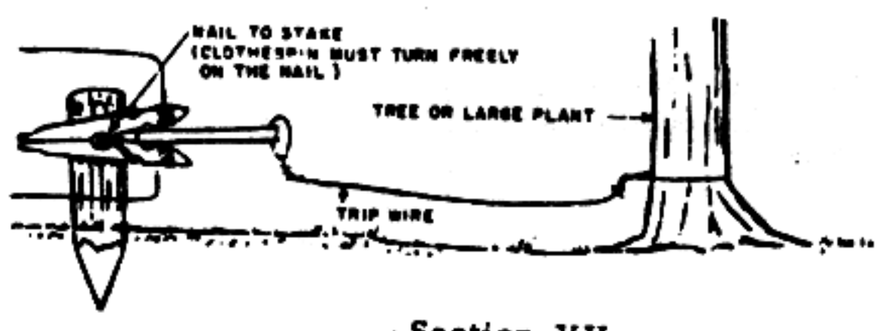


When the flat piece of wood is removed by pulling the string, the jaws of the clothespin will close completing the circuit.

CAUTION

Do not attach the battery until the switch and trip wire have been emplaced and examined. Be sure the flat piece of wood is separating the jaws of the switch.

A Method of Use

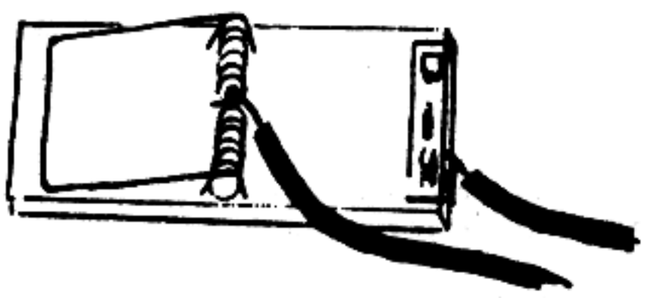


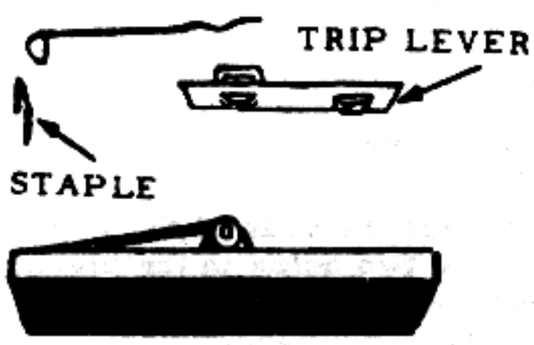
135 Section VII No. 2
MOUSETRAP SWITCH

A common mousetrap can be used to make a circuit closing switch for electrically initiated explosives, mines and booby traps.

MATERIEL REQUIRED:

Mousetrap
Hacksaw or File
Connecting wires



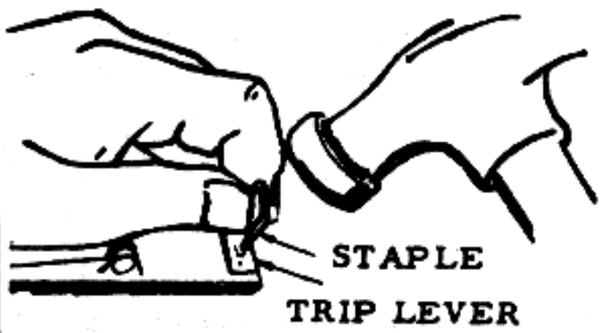


PROCEDURE:

1. Remove the trip lever from the mousetrap using a hacksaw or file. Also remove the staple and holding wire.

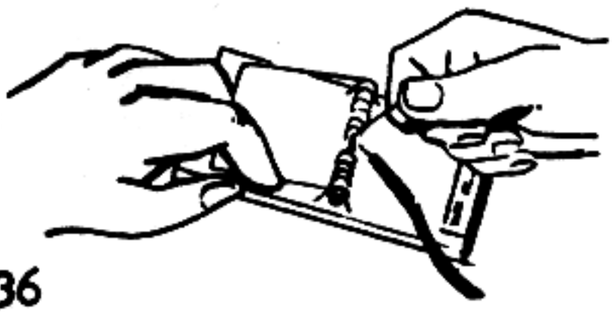
2. Retract the striker of the mousetrap and attach the trip lever across the end of the wood base using the staple with which the holding wire was attached.

NOTE: If the trip lever is not made of metal, a piece of metal of approximately the same size should be used.



3. Strip one in. (2 1/2 cm) of insulation from the ends of 2 connecting wires.

4. Wrap one wire tightly around the spring loaded striker of the mousetrap.



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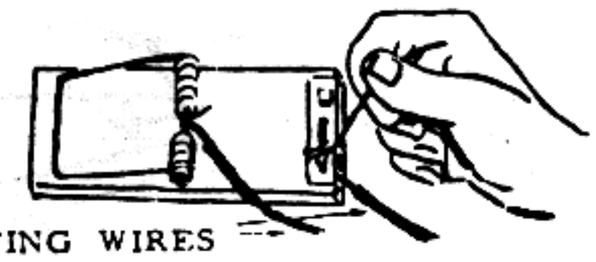
5. Wrap the second wire around some part of the trip lever or piece of metal.

NOTE: If a soldering iron is available, solder both of the wires in place.

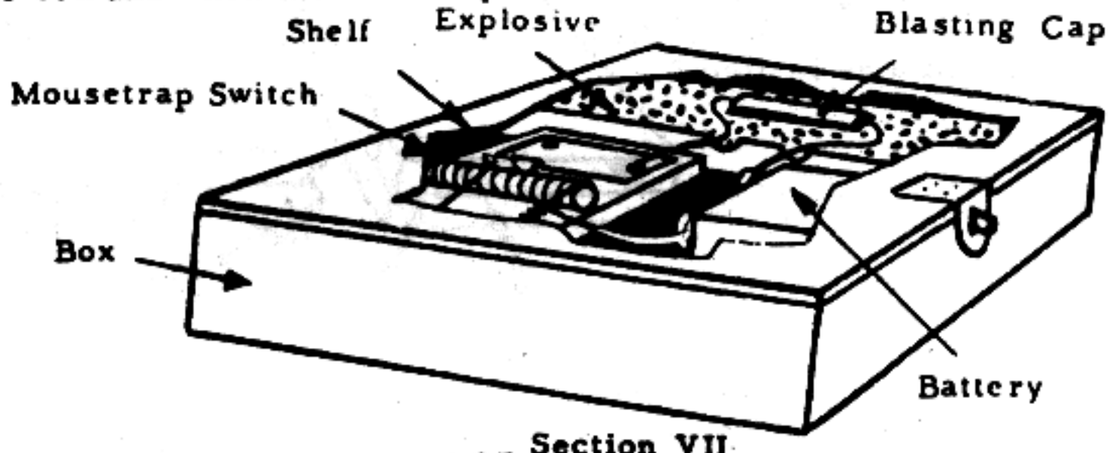


CONNECTING WIRES

HOW TO USE:

This switch can be used in a number of ways -- one typical method is presented here.

The switch is placed inside a box which also contains the explosive and batteries. The spring loaded striker is held back by the lid of the box and when the box is opened the circuit is closed.

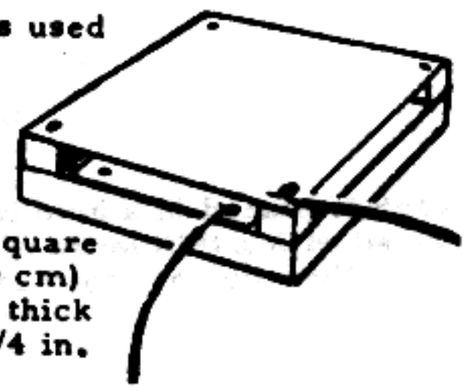


137 Section VII No. 3
FLEXIBLE PLATE SWITCH

This pressure sensitive switch is used for initiating emplaced mines and explosives.

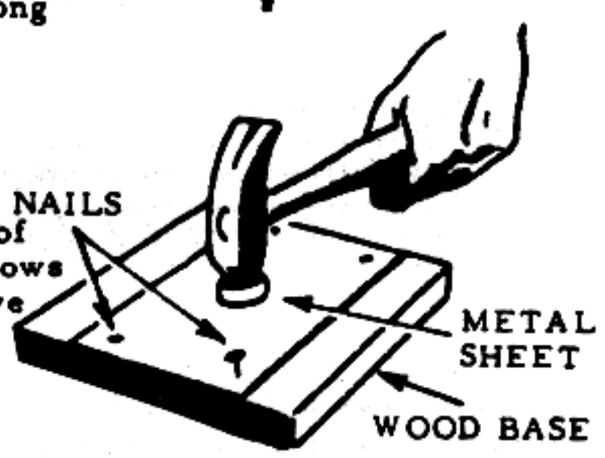
MATERIAL REQUIRED:

Two flexible metal sheets
  one approximately 10 in. (25 cm) square
  one approximately 10 in. x 8 in.(20 cm)
Piece of wood 10 in. square by 1 in. thick
Four soft wood blocks 1 in.x 1 in.x 1/4 in.
Eight flat head nails, 1 in. long
Connecting wires
Adhesive tape

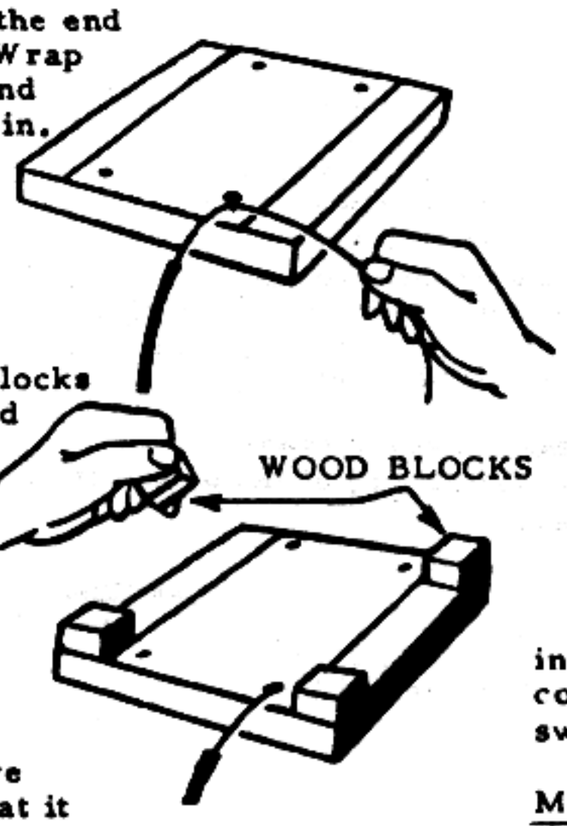


PROCEDURE:

1. Nail 10 in. x 8 in. metal sheet to 10 in. square piece of wood so that 1 in. of wood shows on each side of metal. Leave one of the nails sticking up about 1/4 in.

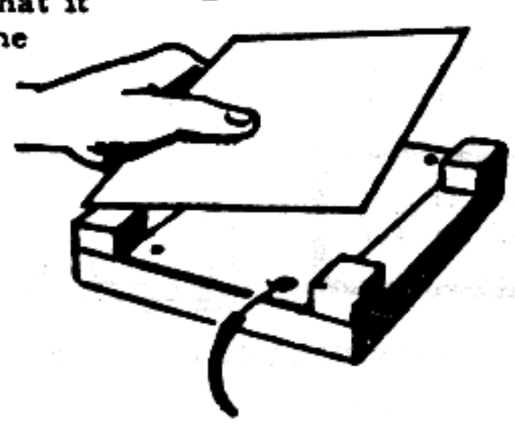


2. Strip insulation from the end of one connecting wire. Wrap this end around the nail and drive the nail all the way in.



3. Place the four wood blocks on the corners of the wood base.

4. Place the 10 in. square flexible metal sheet so that it rests on the blocks in line with the wood base.



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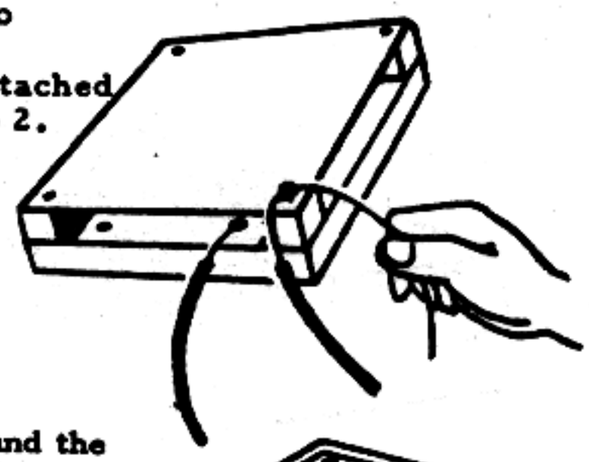
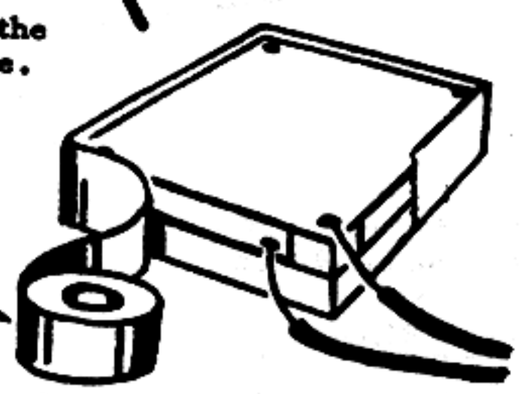
5. Drive four nails through the metal sheet and the blocks to fasten to the wood base. A second connecting wire is attached to one of the nails as in Step 2.

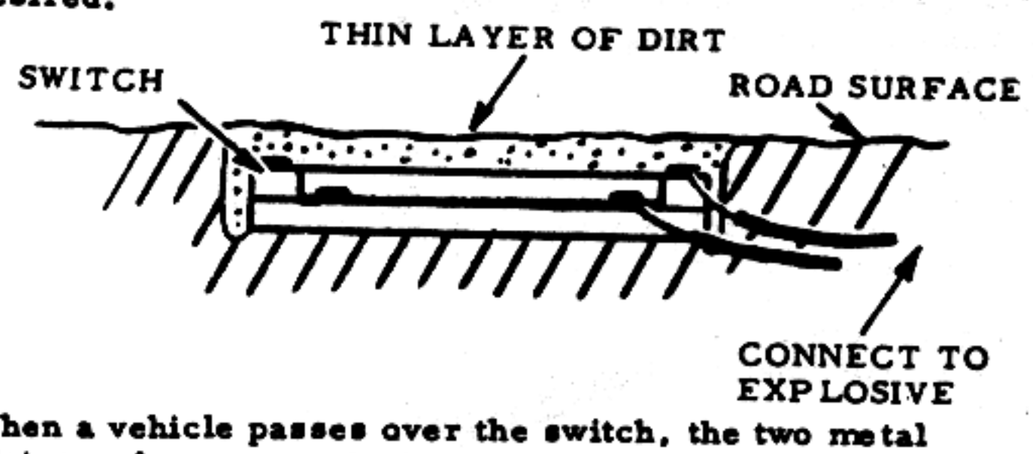


6. Wrap adhesive tape around the edges of the plate and wood base. This will assure that no dirt or other foreign matter will get between the plates and prevent the switch from operating.

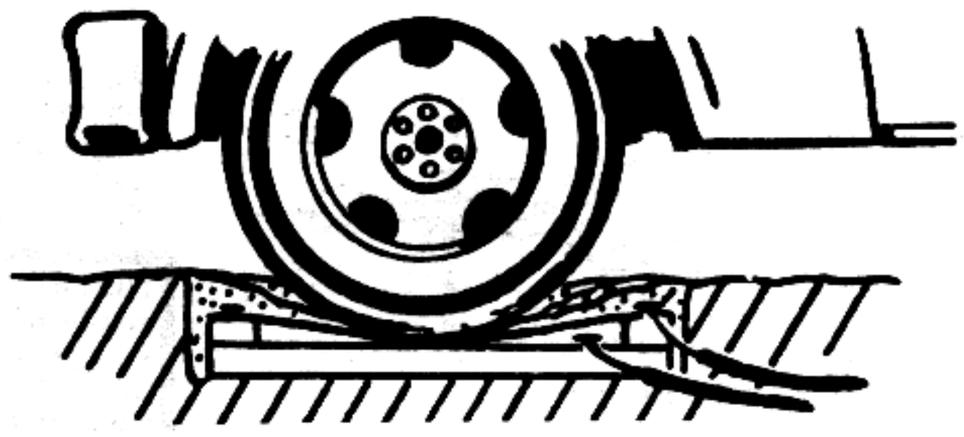


HOW TO USE:

The switch is placed in a hole in the path of expected traffic and covered with a thin layer of dirt or other camouflaging material. The mine or other explosive device connected to the switch can be buried with the switch or emplaced elsewhere as desired.



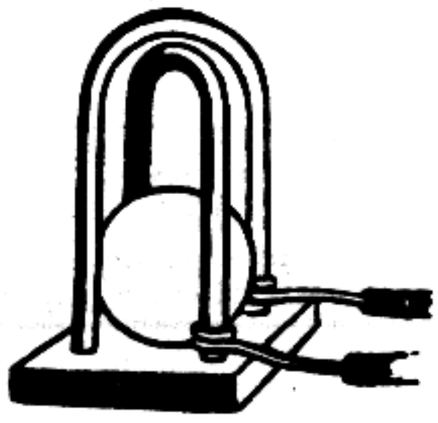
When a vehicle passes over the switch, the two metal plates make contact closing the firing circuit.



Section VII
139 No. 4

METAL BALL SWITCH

This switch will close an electric circuit when it is tipped in any direction. It can be used alone for booby traps or in combination with another switch or timer as an anti-disturbance switch.



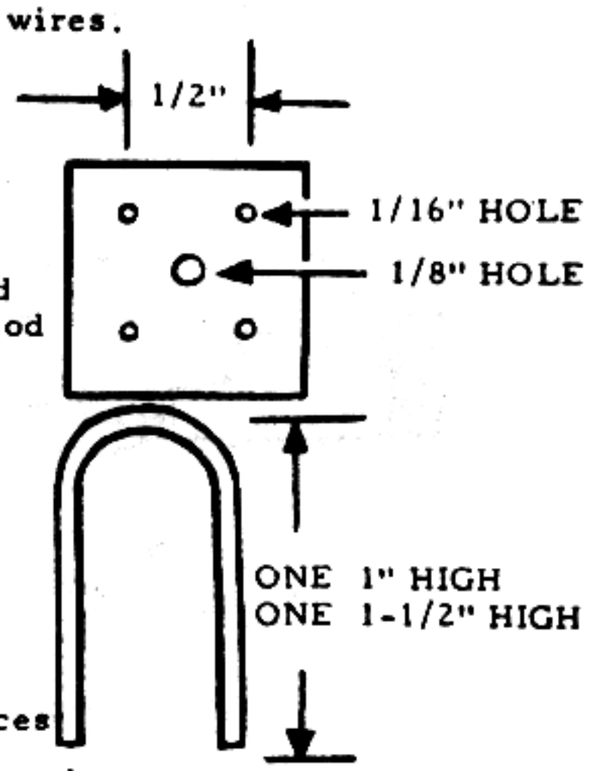
MATERIAL REQUIRED:

Metal Ball 1/2" (1 1/4 cm) diameter (see Note)
Solid copper wire 1/16" (1/4 cm) diameter
Wood block 1" (2 1/2 cm) square by 1/4" thick
Hand drill
Connecting wires
Soldering iron & solder

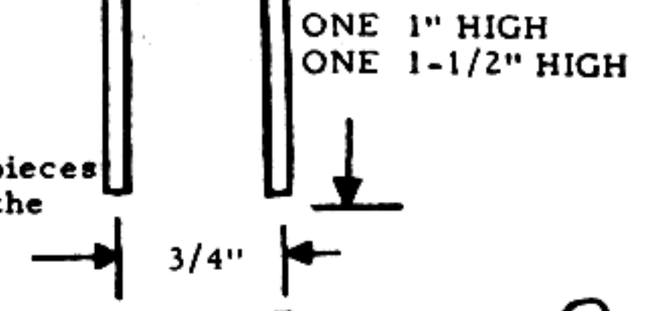
NOTE: If other than a 1/2" diameter ball is used, other dimensions must be changed so that the ball will rest in the center hole of the block without touching either of the wires.

PROCEDURE:

1. Drill four 1/16" holes and one 1/8" hole through the wood block as shown.



2. Form two "U" shaped pieces from 1/16" copper wire to the dimensions shown.



3. Wrap a connecting wire around one leg of each "U" at least 1/4" from the end and solder in place.

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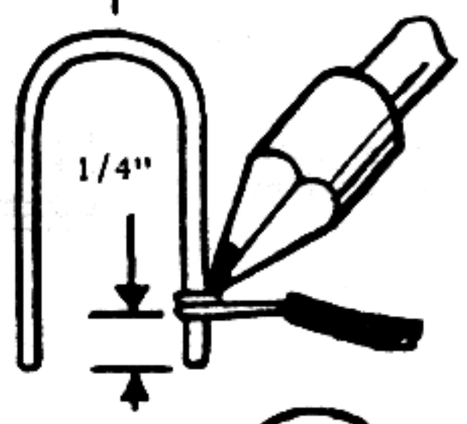
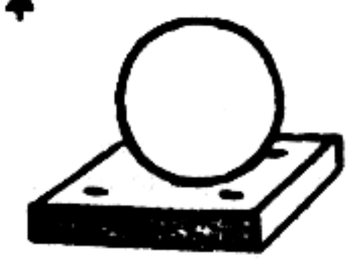
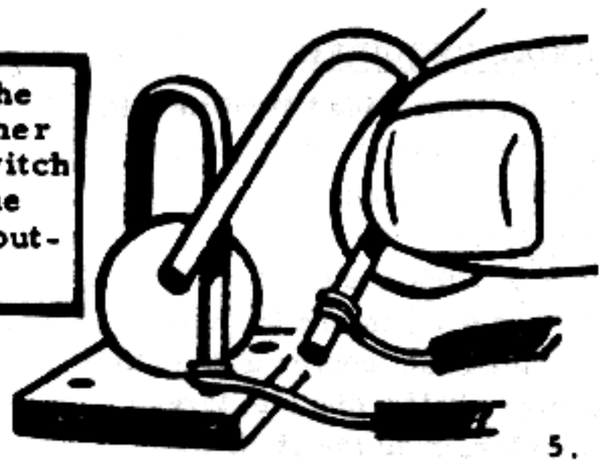


4. Place metal ball on block so that it rests in the center hole.

5. Insert the ends of the small "U" into two holes in the block. Insert large "U" into the remaining two holes.



CAUTION: Make sure that the metal ball does not touch either "U" shaped wire when the switch is standing on its base. If the ball does touch, bend wires outward slightly.



HOW TO USE:

Mount switch vertically and connect in electrical firing circuit as with any other switch. When tipped in any direction it will close the circuit.

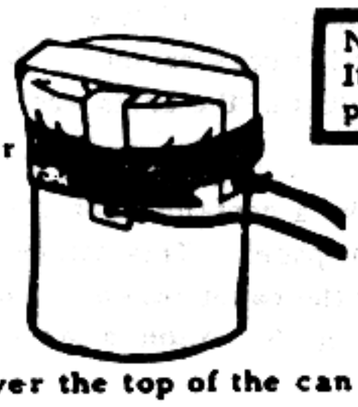
CAUTION: Switch must be mounted vertically and not disturbed while completing connections.

Section VII
141 No. 5
ALTIMETER SWITCH

This switch is designed for use with explosives placed on aircraft. It will close an electrical firing circuit when an altitude of approximately 5000 ft (1-1/2 KM) is reached.

MATERIAL REQUIRED:

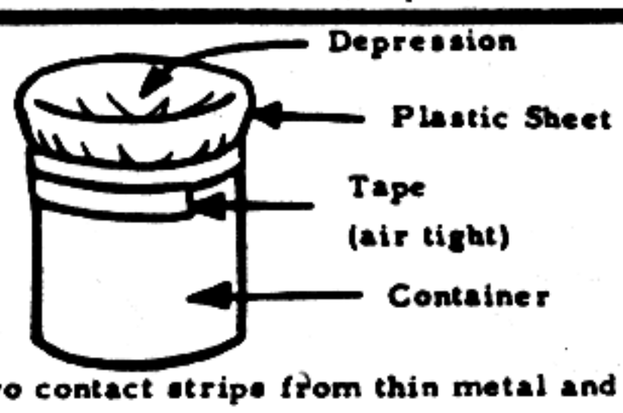
Jar or tin can
Thin sheet of flexible plastic or waxed paper
Thin metal sheet (cut from tin can)
Adhesive Tape
Connecting Wires



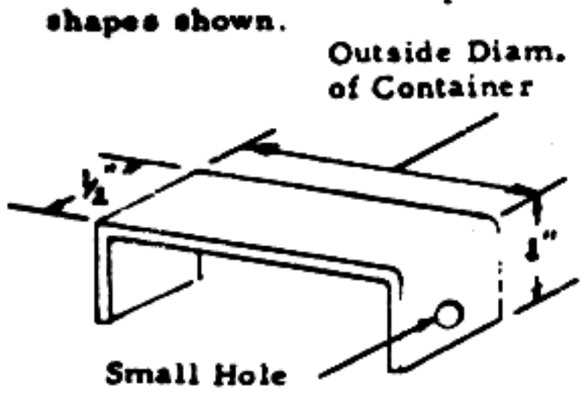
PROCEDURE:

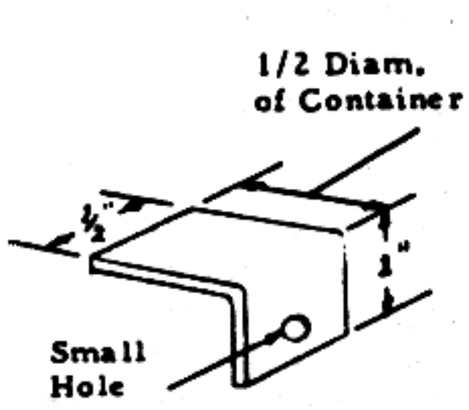
1. Place sheet of plastic or waxed paper over the top of the can or jar and tape tightly to sides of container.

NOTE: Plastic sheet should not be stretched tight. A small depression should be left in the top.



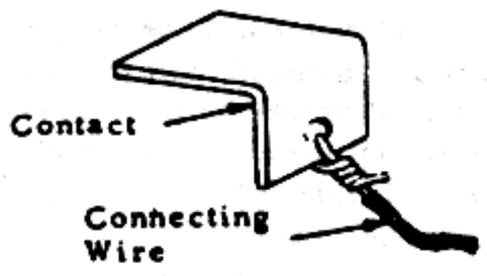
2. Cut two contact strips from thin metal and bend to the shapes shown.





3. Strip insulation from the ends of two connecting wires. Attach one wire to each contact strip.

NOTE: If a soldering iron is available solder wires in place.



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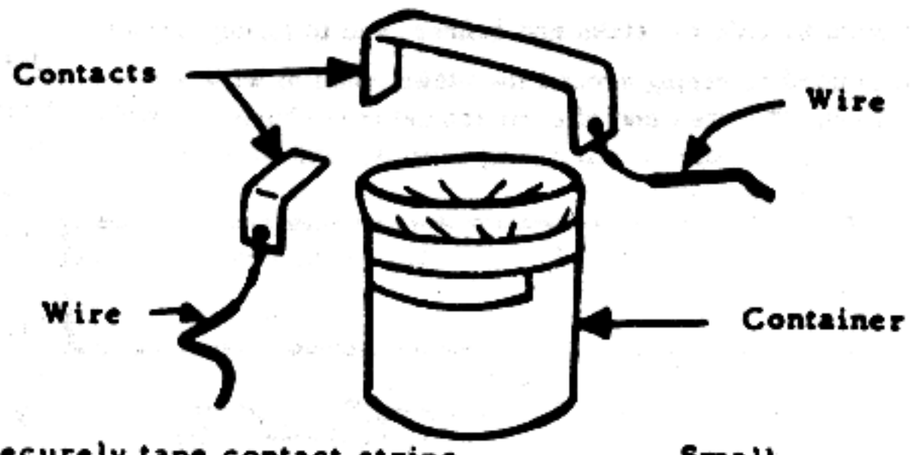
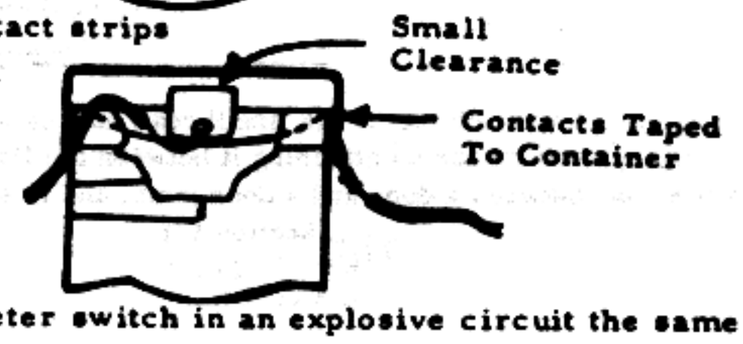
4. Place contact strips over container so that the larger contact is above the smaller with a very small clearance between the two.



5. Securely tape contact strips to sides of container.



HOW TO USE:

1. Connect the altimeter switch in an explosive circuit the same as any switch.

2. Place the explosive package on airplane. As the plane rises the air inside the container will expand. This forces the plastic sheet against the contacts closing the firing circuit.

NOTE: The switch will not function in a pressurized cabin. It must be placed in some part of the plane which will not be pressurized.

Section VII
143 No. 6
PULL-LOOP SWITCH

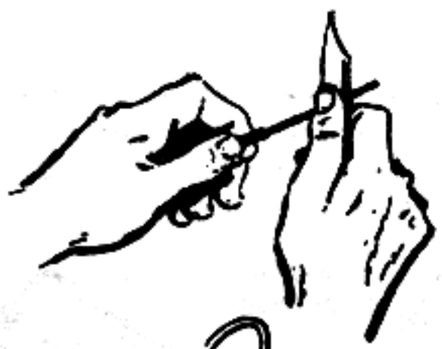
This switch will initiate explosive charges, mines, and booby traps when the trip wire is pulled.

MATERIAL REQUIRED:

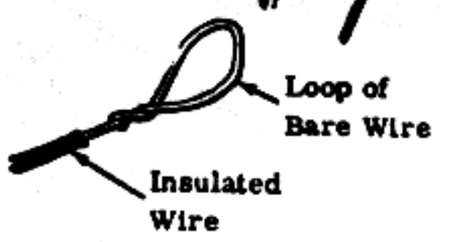
2 lengths of insulated wire
Knife
Strong string or cord
Fine thread that will break easily

PROCEDURE:

1. Remove about 2 inches of insulation from one end of each length of wire. Scrape bare wire with knife until metal is shiny.



2. Make a loop out of each piece of bare wire.



3. Thread each wire through the loop of the other wire so the wires can slide along each other.

NOTE: The loops should contact each other when the two wires are pulled taut.

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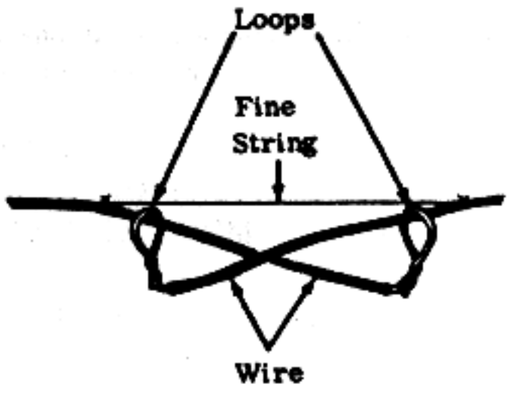
HOW TO USE:

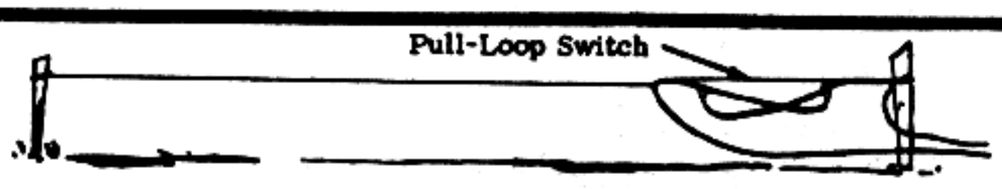
1. Separate loops by about 2 inches. Tie piece of fine thread around wires near each loop Thread should be taut enough to support loops and wire, yet fine enough that it will break under a very slight pull.



2. Fasten one wire to tree or stake and connect end to firing circuit.

3. Tie a piece of cord or string around the other piece of wire a few inches from the loop. Tie free end of cord around tree, bush, or stake. Connect the free end of the wire to the firing circuit. Initiation will occur when the tripcord is pulled.

CAUTION: Be sure that the loops do not contact each other when the wires are connected to the firing circuit.



OTHER USES: The switch minus the fine thread may be used to activate a booby trap by such means as attaching it between the lid and a rigid portion of a box, between a door and a door jamb, and in similar manners.

Section VII
145 No. 7
KNIFE SWITCH

This device will close the firing circuit charges, mines, and booby traps when the trip wire is pulled or cut.

MATERIAL REQUIRED:

Knife or hack saw blade
6 nails
Strong string or light rope
Sturdy wooden board
Wire

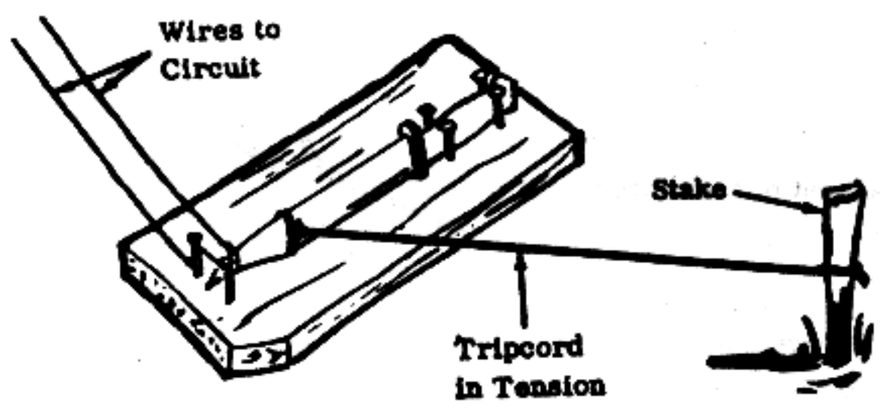
PROCEDURE:

1. Place knife on board. Drive 2 nails into board on each side of knife handle so knife is held in place.

2. Drive one nail into board so that it touches blade of knife near the point.

3. Attach rope to knife. Place rope across path. Apply tension to rope, pulling knife blade away from nail slightly. Tie rope to tree, bush, or stake.

4. Drive another nail into board near the tip of the knife blade as shown below. Connect the two nails with a piece of conducting wire. Nail should be positioned so that it will contact the second nail when blade is pulled about 1 inch (2-1/2 cm) to the side.



NOTE: Check position of nails to knife blade. The nails should be placed so that the knife blade will contact either one when the rope is pulled or released.

HOW TO USE:

Attach one wire from firing circuit to one of the nails and the other to the knife blade. The circuit will be completed when the tripcord is pulled or released.

Section VII
146 No. 8
IMPROVISED SCALE

This scale provides a means of weighing propellant and other items when conventional scales or balances are not available.

MATERIAL REQUIRED:

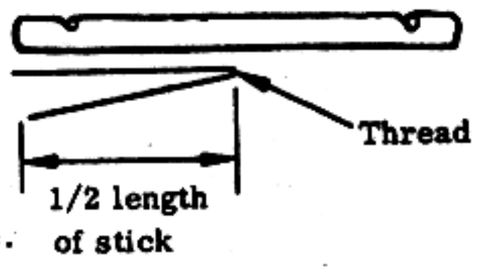
Pages from Improvised Munitions Handbook
Straight sticks about 1 foot (30 cm) long and 1/4 in. (5 mm) in diameter
Thread or fine string

PROCEDURE:

1. Make a notch about 1/2 in. (1 cm) from each end of stick. Be sure that the two notches are the same distance from the end of the stick.

2. Find the exact center of the stick by folding in half a piece of thread the same length as the stick and placing it alongside the stick as a ruler. Make a small notch at the center of the stick.

3. Tie a piece of thread around the notch. Suspend stick from branch, another stick wedged between rocks, or by any other means. Be sure stick is balanced and free to move.



NOTE: If stick is not balanced, shave or scrape a little off the heavy end until it does balance. Be sure the lengths of the arms are the same.

4. Make a container out of one piece of paper. This can be done by rolling the paper into a cylinder and folding up the bottom a few times.

5. Punch 2 holes at opposite sides of paper container. Suspend container from one side of stick.

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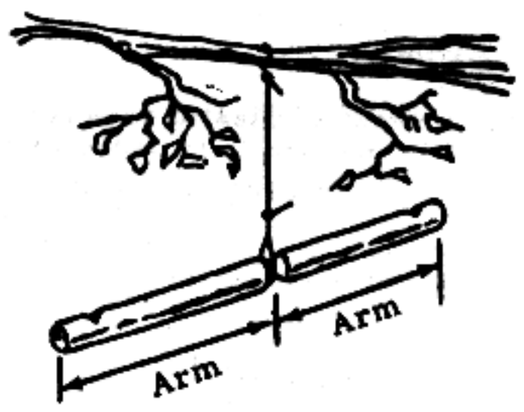
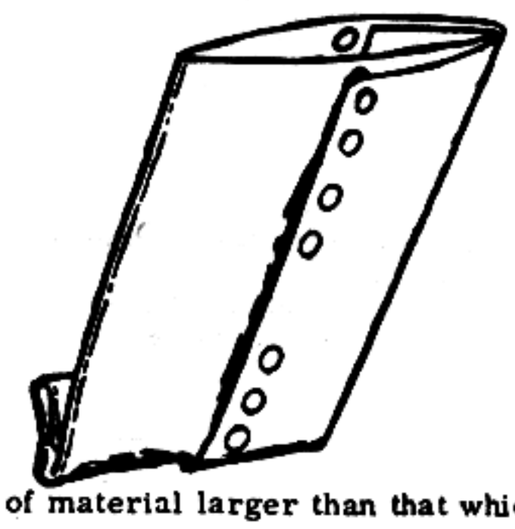
6. Count out the number of handbook pages equal in weight to that of the quantity of material to be weighed. Each sheet of paper weighs about 1.3 grams (20 grains or .04 ounce). Suspend these sheets, plus one, to balance container on the other side of the scale.

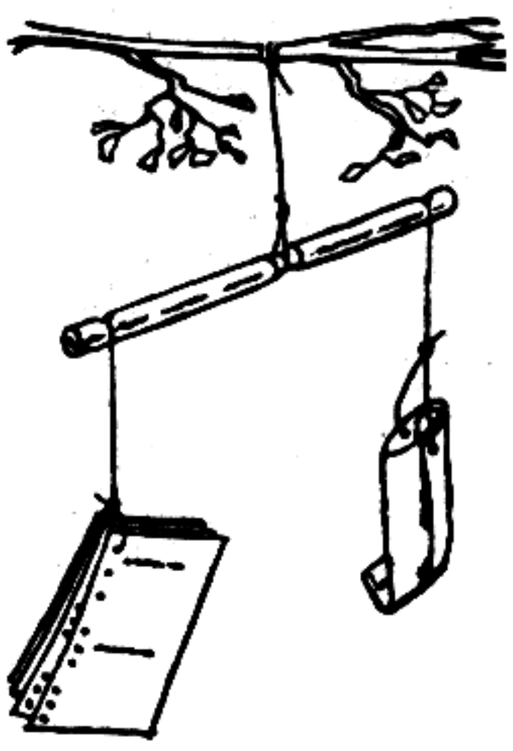




7. Slowly add the material to be weighed to the container. When the stick is balanced, the desired amount of material is in the container.

8. If it is desired to weigh a quantity of material larger than that which would fit in the above container, make a container out of a larger paper or paper bag, and suspend from one side of the stick. Suspend handbook pages from the other side until the stick is balanced. Now place a number of sheets of handbook pages equal in weight to that of the desired amount of material to be weighed on one side, and fill the container with the material until the stick is balanced.

9. A similar method may be used to measure parts or percentage by weight. The weight units are unimportant. Suspend equal weight containers from each side of the stick. Bags, tin cans, etc. can be used. Place one material in one of the containers. Fill the other container with the other material until they balance. Empty and refill the number of times necessary to get the required parts by weight (e.g., 5 to 1 parts by weight would require 5 fillings of one can for one filling of the other).



Section VII
148 No. 9
ROPE GRENADE LAUNCHING TECHNIQUE

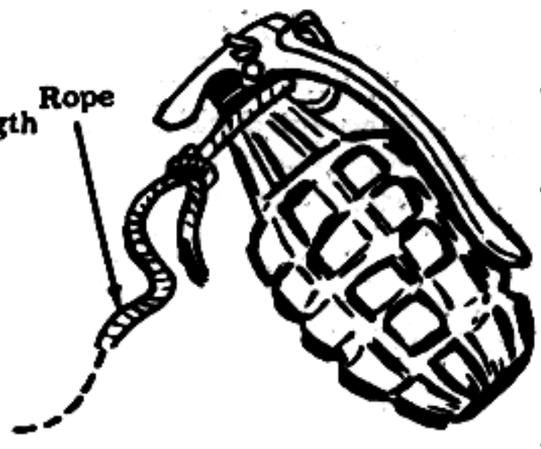
A method of increasing the distance a grenade may be thrown. Safety fuse is used to increase the delay time.

MATERIAL REQUIRED:

Hand grenade (Improvised pipe hand grenade, Section II, No. 1 may be used)
Safety fuse or fast burning Improvised Fuse, (Section VI, No. 7)
Light rope, cord, or string

PROCEDURE:

1: Tie a 4 to 6 foot (1 meter) length of cord to the grenade. Be sure that the rope will not prevent the grenade handle from coming off.

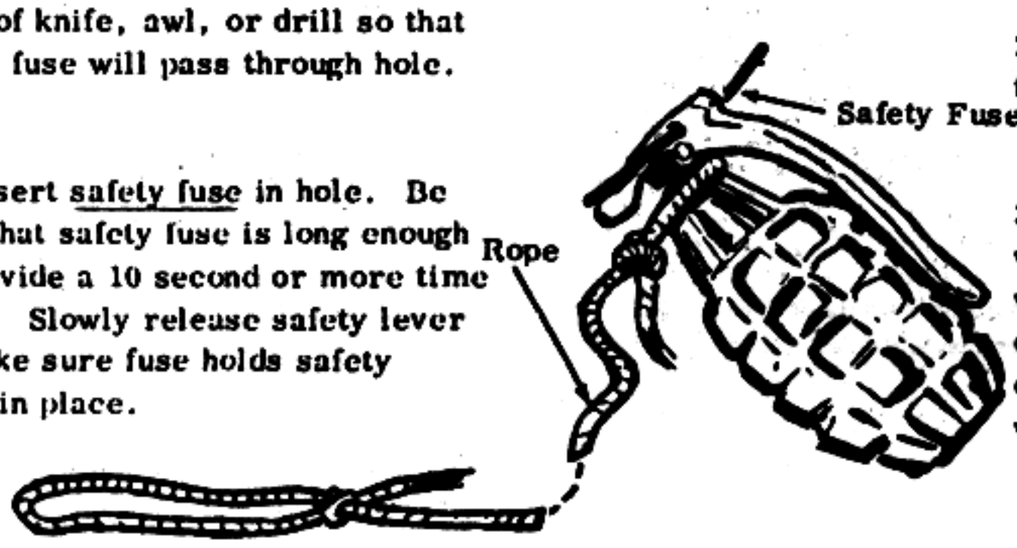


Note: If improvised grenade is used, tie cord around grenade near the end cap. Tape in place if necessary.

2. Tie a large knot in the other end of the cord for use as a handle.

3. Carefully remove safety pin from grenade, holding safety lever in place. Enlarge safety pin hole with point of knife, awl, or drill so that safety fuse will pass through hole.

4. Insert safety fuse in hole. Be sure that safety fuse is long enough to provide a 10 second or more time delay. Slowly release safety lever to make sure fuse holds safety lever in place.



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CAUTION: If safety lever should be released for any reason, grenade will explode after regular delay time (4-5 sec.).

NOTE: If diameter of safety fuse is too large to fit in hole (Step 4), follow procedure and How to Use of Time Delay Grenade, Section VI, No. 9, instead of Steps 3 and 4 above.

HOW TO USE:

1. Light fuse.

2. Whirl grenade overhead, holding knot at end of rope, until grenade picks up speed (3 or 4 turns).

3. Release when sighted on target.

CAUTION: Be sure to release grenade within 10 seconds after fuse is lit.

NOTE: It is helpful to practice first with a dummy grenade or a rock to improve accuracy. With practice, accurate launching up to 100 meters (300 feet) can be obtained.

Section VII
150 No. 10
BICYCLE GENERATOR POWER SOURCE

A 6 volt, 3 watt bicycle generator will set off one or two blasting caps (connected in series) or an igniter.

MATERIAL REQUIRED:

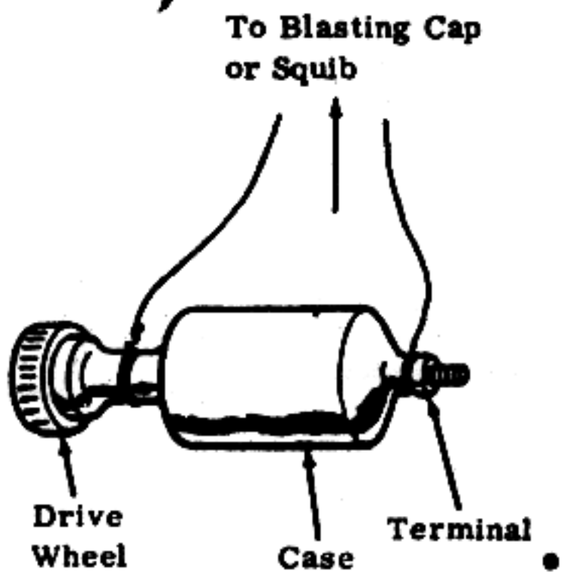
Bicycle generator (6 volts, 3 watt)
Copper wire
Knife

PROCEDURE:

1. Strip about 4 in. (10 cm) of coating from both ends of 2 copper wires. Scrape ends with knife until metal is shiny.

2. Connect the end of one wire to the generator terminal.

3. Attach the end of the second wire to generator case. This wire may be wrapped around a convenient projection, taped, or simply held against the case with the hand.



HOW TO USE:

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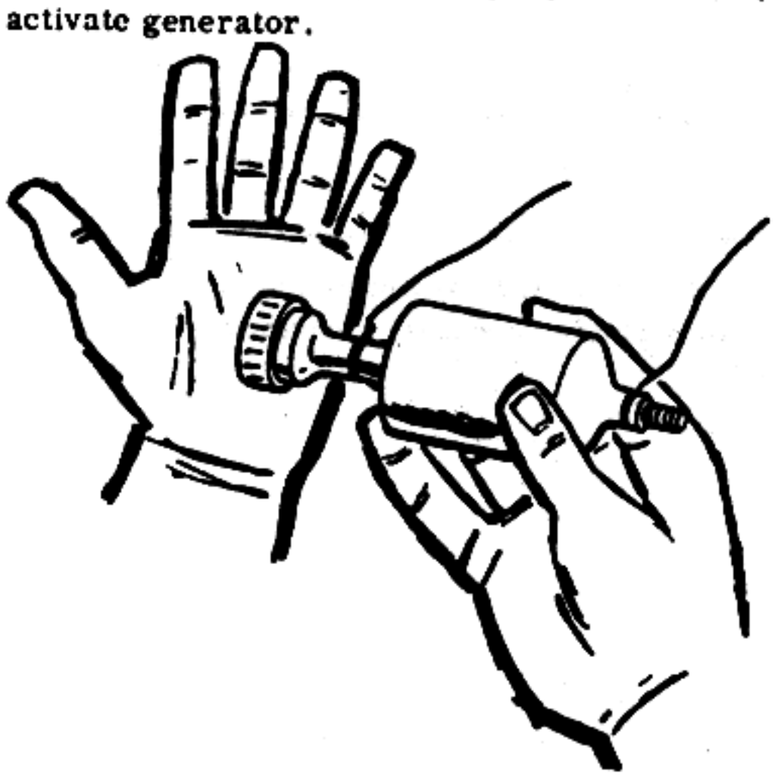
1. Connect free ends of wires to blasting cap or squib leads.

CAUTION: If drive wheel is rotated, explosive may be set off.

2. Run the drive wheel firmly and rapidly across the palm of the hand to activate generator.



Section VII
152 No. 11

AUTOMOBILE GENERATOR POWER SOURCE

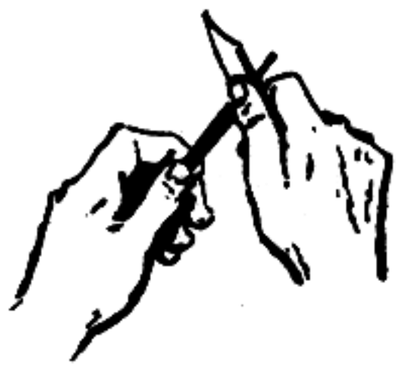
An automobile generator can be used as a means of firing one blasting cap or igniter. (Improvised Igniter, Section V, No. 2, may be used.)

MATERIAL REQUIRED:

Automobile generator (6, 12, or 28 volts). (An alternator will not work.)
Copper Wire
Strong string or wire, about 5 ft. (150 cm) long and 1/16 in. (1-1/2 mm) in diameter
Knife
Small light bulb requiring same voltage as generator, (for example, bulb from same vehicle as generator).

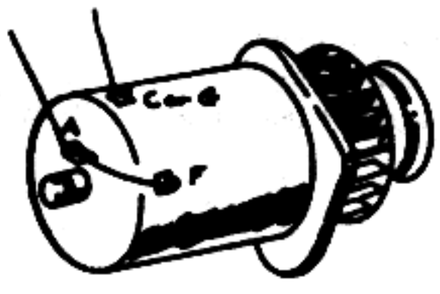
PROCEDURE:

1. Strip about 1 in. (2-1/2 cm) of coating from both ends of 3 copper wires. Scrape ends with knife until metal is shiny.



2. Connect the A and F terminals with one piece of wire.

3. Connect a wire to the A terminal. Connect another to the G terminal.



NOTE: The F and G or C terminals may not be labeled; in this case, connect wires as shown. The F terminal is usually smaller in size than the C or G terminal.

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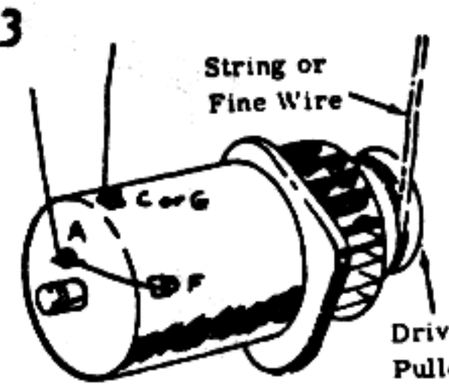
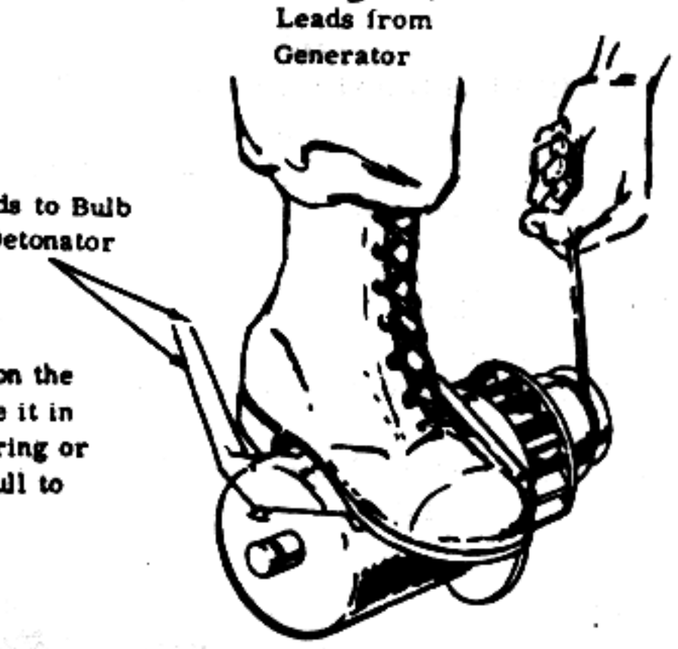
4. Wrap several turns of string or wire clockwise around the drive pulley.



HOW TO USE:

1. Connect the free ends of the wires to the light bulb.

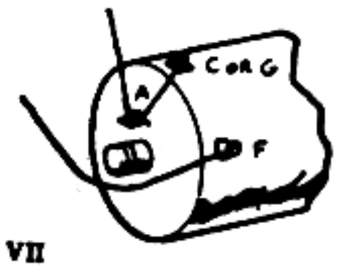


2. Place one foot on the generator to secure it in place. Give the string or wire a very hard pull to light the bulb.

NOTE: If not successful at first, rewind string and try again several times. After repeating this operation and the bulb still does not light, follow Step 4, "How to Use."

3. If light bulb lights, follow Steps 1 and 2 of above, "How to Use," connecting free ends of wires to blasting cap or igniter instead of to light bulb.

4. If light bulb does not light after several pulls, switch leads connected to F and G terminals. Repeat above "How to Use," Steps 1 to 3.



Section VII
154 No. 12

IMPROVISED BATTERY (SHORT LASTING)

This battery is powerful but must be used within 15 minutes after fabrication. One cell of this battery will detonate one blasting cap or one igniter. Two cells, connected in series, will detonate two of these devices and so on. Larger cells have a longer life as well as greater power.

MATERIALS	COMMON SOURCE
Water	
Sodium hydroxide (lye, solid or concentrated solution)	Soap manufacturing Disinfectants Sewer cleaner
Copper or brass plate about 4 in. (10 cm) square and 1/16 in. (2 mm) thick	

Aluminum plate or sheet, same size as copper plate

Charcoal powder

Container for mixing

Knife

One of the following:

Potassium permanganate, solid	Disinfectants Deodorants
Calcium hypochlorite, solid	Disinfectants Water treating chemicals Chlorine bleaches
Manganese dioxide (pyrolucite)	Dead dry-cell batteries

NOTE: Be sure sodium hydroxide solution is at least a 45% solution by weight. If not, boil off some of the water. If solid sodium hydroxide is available, dissolve some sodium hydroxide in about twice as much water (by volume).

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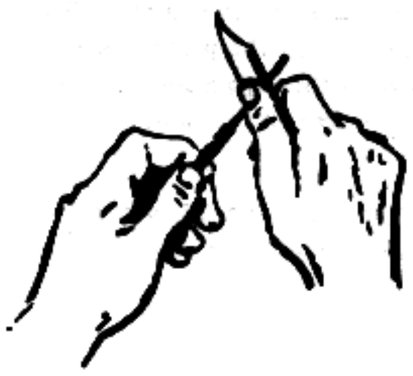
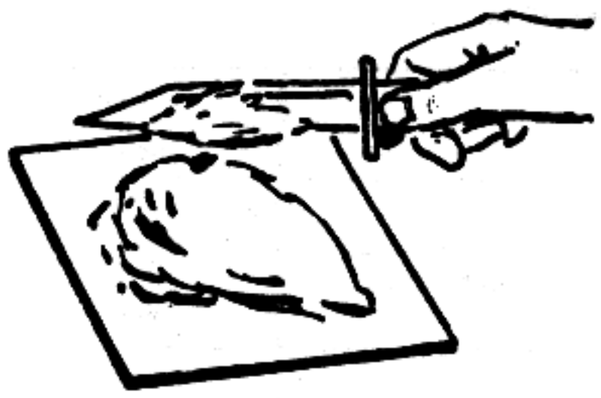
PROCEDURE:



1. Scrape coating off both ends of wires with knife until metal is shiny.

2. Mix thoroughly (do not grind) approximately equal volumes of powdered charcoal and one of the following: potassium permangenate, calcium hypochlorite, or manganese dioxide. Add water until a very thick paste is formed.

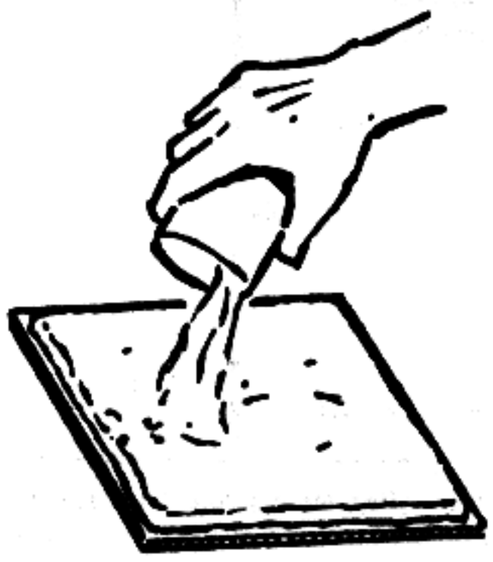
CAUTION: Avoid getting any of the ingredient on the skin or in the eyes.



3. Spread a layer of this mixture about 1/8 in. (2 mm) thick on the copper or brass plate. Be sure mixture is thick enough so that when mixture is sandwiched between two metal plates, the plates will not touch each other at any point.

NOTE: If more power is required, prepare several plates as above.

HOW TO USE:



1. Just prior to use (no more than 15 minutes), carefully pour a small quantity of sodium hydroxide solution over the mixture on each plate used.

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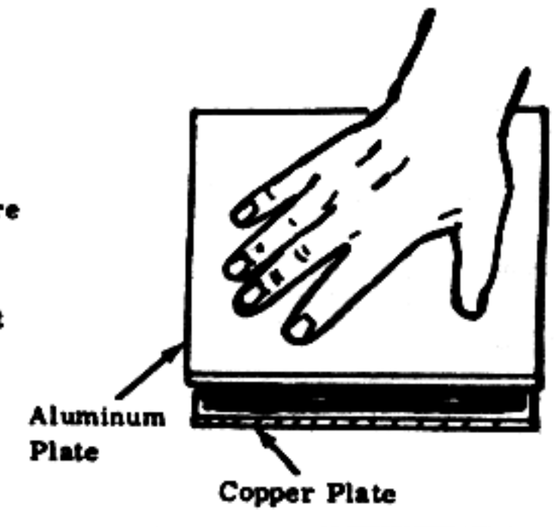
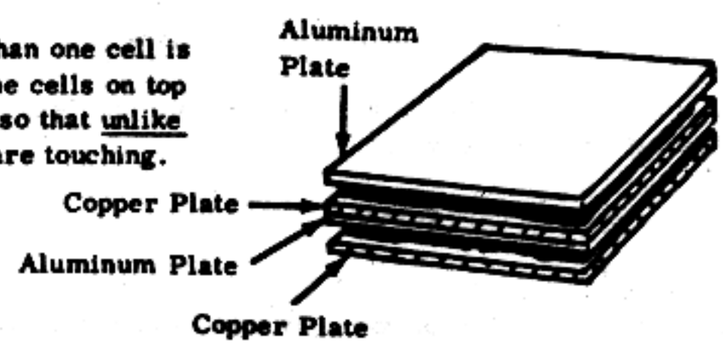
CAUTION: If solution gets on skin, wash off immediately with water.



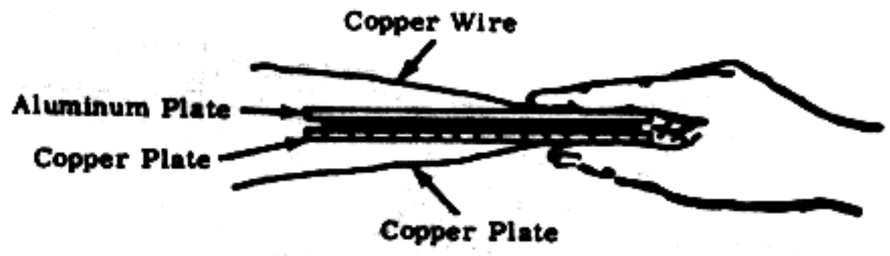
2. Place an aluminum plate on top of the mixture on each copper plate. Press firmly. Remove any excess that oozes out between the plates.

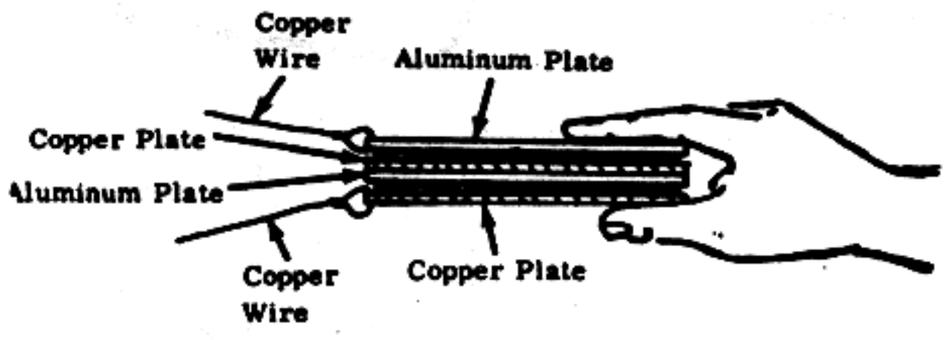
CAUTION: Be sure plates are not touching each other at any point.



3. If more than one cell is used, place the cells on top of each other so that unlike metal plates are touching.

4. When ready to fire, clean plates with knife where connections are to be made. Connect one wire to the outer aluminum plate. This may be done by holding the wires against the plates or by hooking them through holes punched through plates. If wires are hooked through plates, be sure they do not touch mixture between plates.





157 Section VII
No. 13

IMPROVISED BATTERY (2 HOUR DURATION)

This battery should be used within 2 hours and should be securely wrapped. Three cells will detonate one blasting cap or one igniter. Five cells, connected in series, will detonate two of these devices and so on. Larger cells have a longer life and will yield more power.

If depolarizing materials such as potassium permanganate or manganese dioxide cannot be obtained, ten cells without depolarizer, arranged as described below, (Step 4) will detonate one blasting cap.

MATERIALS	COMMON SOURCE
Water	
Ammonium chloride (sal ammoniac) (solid or concentrated solution)	Medicines Soldering fluxes Fertilizers Ice melting chemicals for roads

Charcoal powder

Copper or brass plate about 4 in. (10 cm) square and 1/16 in. (2 mm) thick

Aluminum plate same size as copper or brass plate

Wax and paper (or waxed paper) — **Candles**

Wire, string or tape

Container for mixing

Knife

<u>One of the following</u>:

Potassium permanganate, solid — **Disinfectants, Deodorants**

Manganese dioxide — **Dead dry batteries**

NOTE: If ammonium chloride solution is not concentrated (at least 45% by weight) boil off some of the water.

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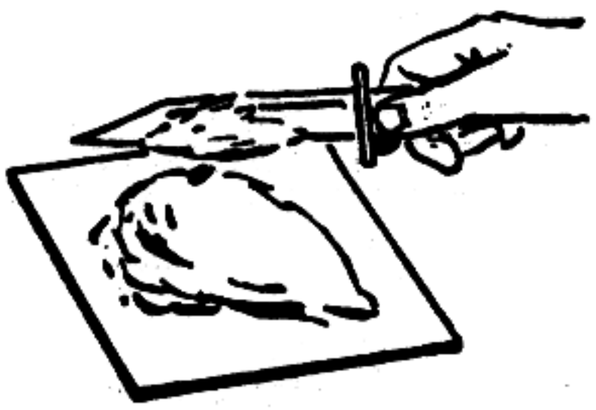
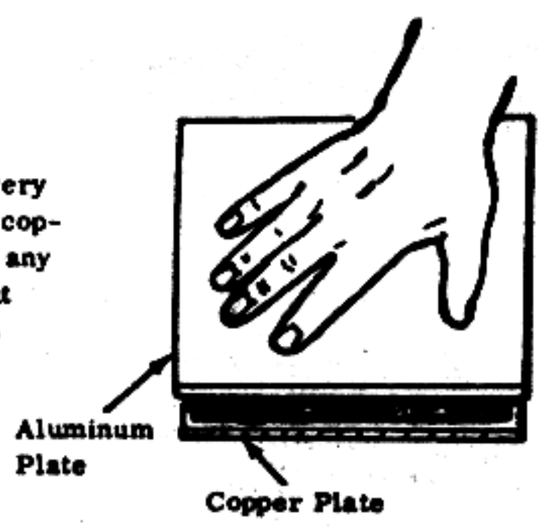
PROCEDURE:

1. Mix thoroughly (do not grind) approximately equal volumes of powdered charcoal, ammonium chloride and <u>one</u> of the following: potassium permanganate or manganese dioxide. Add water until a very thick paste is formed. If ammonium chloride is in solution form, it may not be necessary to add water.

2. Spread a layer of this mixture, about 1/8 in. (3 mm) thick, on a clean copper or brass plate. The layer must be thick enough to prevent a second plate from touching the copper plate when it is pressed on top.

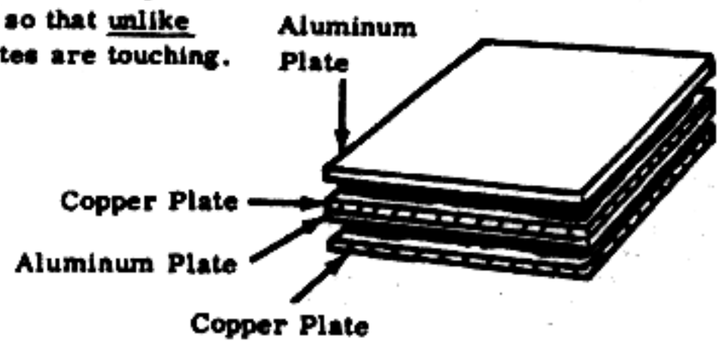


3. Press an aluminum plate very firmly upon the mixture on the copper plate. Remove completely any of the mixture that squeezes out between the plates. <u>The plates must not touch</u>.



4. If more than one cell is desired:

   a. Place one cell on top of the other so that <u>unlike</u> metal plates are touching.



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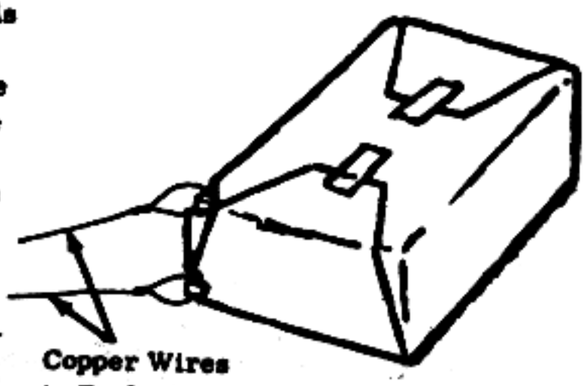
   b. Wrap the combined cells in heavy waxed paper. The waxed paper can be made by rubbing candle wax over one side of a piece of paper. Secure the paper around the battery with string, wire or tape. Expose the top and bottom metal plates at one corner.



<u>HOW TO USE</u>:

1. Scrape a few inches off each end of two wires with knife till metal is shiny.

2. Clean plates with knife until metal is shiny where connections are to be made.

3. Connect one wire from the explosive to a copper or brass plate and the other wire to an aluminum plate. The connection can be made by holding the wire against the plate. A permanent connection can be made by hooking the wire through holes in the exposed corners of the plates. The battery is now ready for use.

NOTE: If battery begins to fail after a few firings, scrape the plates and wires where connections are made until metal is shiny.

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ARMOR MATERIALS

The following table shows the amount of indigenous materials needed to stop ball type projectiles of the 5.56 mm, .30 caliber, and .50 caliber ammunition fired from their respective weapons at a distance of 10 feet (3 m).

INDIGENOUS MATERIAL	THICKNESS OF MATERIALS					
	Inches			Centimeters		
	5.56 mm	.30 cal 7.62 mm	.50 cal 12.70 mm	5.56 mm	.30 cal 7.62 mm	.50 cal 12.70 mm
Mild steel (structural)	1/2	1/2	3/4	1 1/4	1 1/4	2
Mild aluminum (structural)	1	1	2	2 1/2	2 1/2	5
Pine wood (soft)	14	22	32	36	56	82
Broken stones (cobble gravel)	3	4	11	8	11	28
Dry sand	4	5	14	11	13	36
Wet sand or earth	6	13	21	16	33	54

NOTE: After many projectiles are fired into the armor, the armor will break down. More material must be added.

FM 5-25

DEPARTMENT OF THE ARMY FIELD MANUAL

EXPLOSIVES AND DEMOLITIONS

HEADOUARTERS. OEPARTMENT OF THE ARMV

MAY 1961

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FIELD MANUAL
No. 5–25

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C. *26 May 1967*

EXPLOSIVES AND DEMOLITIONS

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CHAPTER 1

DEMOLITION MATERIALS

Section I. INTRODUCTION

1. Purpose and Scope

a. This manual is a guide in the use of explosives in the destruction of military obstacles, and in certain construction projects. The material includes information on—

(1) Types, characteristics, and uses of explosives and auxiliary equipment.

(2) Preparation, placement, and firing of charges.

(3) Charge calculation formulas.

(4) Deliberate and hasty demolition methods for use in the forward zone.

(5) Safety precautions.

(6) Handling, transportation, and storage of explosives.

b. The contents of this manual are applicable to nuclear and nonnuclear warfare.

2. Comments

Users of this manual are encouraged to submit comments or recommendations for improvement. Commends should be referenced to the specific page, paragraph, and line of text. The reasons should be given for each to insure proper understanding and evaluation. Comments should be forwarded directly to the Commandant, U. S. Army Engineer School, Fort Belvoir, Virginia, 22060.

3. Military Demolitions

Military demolitions are the destruction by fire, water, explosive, and mechanical or other means of areas, structures, facilities, or materials to accomplish a military objective. They have offensive and defensive uses: for example, the removal of enemy barriers to facilitate the advance and the construction of friendly barriers to delay or restrict enemy movement.

Section II. MILITARY EXPLOSIVES AND SPECIAL CHARGES

4. Definitions

a. Explosives. Explosives are substances that, through chemical reaction, violently change and release pressure and heat equally in all directions. Explosives are classified as low or high according to the *detonating velocity* or speed (in feet per second) at which this change takes place and other pertinent characteristics.

b. Low Explosives. Low explosives *deflagrate* or change from a solid to a gaseous state relatively slowly over a sustained period (up to 400 meters or 1312 feet per second). This characteristic makes low explosives ideal where pushing or shoving effect is required. Examples are smokeless and black powders.

c. High Explosives. The change in this type explosive to a gaseous state—detonation—occurs almost instantaneously (from 1,000 meters per second (3,280 feet) to 8,500 meters per second (27,888 feet), producing a shattering effect upon the target. High explosives are used where this shattering effect is required—in certain demolition charges and in charges in mines, shells, and bombs.

d. Relative Effectiveness Factor. Explosives vary not only in detonating rate or velocity (feet per second), but also in other characteristics, such as density and heat production, that determine their effectiveness. They vary so much that the amount of explosive used is computed according to a relative effectiveness factor, based on the effectiveness of all high explo-

sives in relation to that of TNT. For example, TNT, with a detonating velocity of 23,000 feet per second, has a relative effectiveness factor of 1, while tetrytol, with the same velocity, has a higher relative effectiveness factor of 1.20 (table VIII).

5. Characteristics of Military Explosives

Explosives used in military operations have certain properties or characteristics essential to their function. These are—

a. Relative insensitivity to shock or friction.

b. Detonating velocity, adequate for the purpose.

c. High power per unit of weight.

d. High density (weight per unit of volume).

e. Stability adequate to retain usefulness for a reasonable time when stored in any climate at temperatures between −80° F and +165° F.

f. Positive detonation by easily prepared primers.

g. Suitability for use under water.

h. Convenient size and shape for packaging, storage, distribution, and handling by troops.

i. Capability of functioning over a wide range of temperatures.

6. Selection of Explosives

The explosives for a particular purpose generally are selected on the basis of velocity of detonation. For example, an explosive having a high detonating velocity generally is used for cutting and breaching; that of a lower velocity, for cratering, ditching, and quarrying. The types of explosives commonly used are described below.

7. TNT (Trinitrotoluene)

a. Characteristics (fig. 1).

Case	Color	Size	Detonating velocity
Cardboard with metal ends; threaded cap well.	¼ lb—OD ½ lb—yellow or OD 1 lb—OD	¼ lb—D 1½ in, L 3½ in; ½ lb—3¾ x 1¾ x 1¾ in; 1 lb—7 x 1¾ x 1¾ in.	23,000 fps

Relative effectiveness	Water resistance	Low temperature effects	Packaging
1.0	Excellent (does not readily absorb water).	Less sensitive to shock.	¼ lb—200 blocks in wooden box; ½ lb—100 blocks in wooden box; 1 lb—50 or 56 blocks in wooden box.

b. Use. TNT is used in cutting and breaching and as a main or booster charge for general demolition purposes in combat areas. To form a charge to fit special targets, it is removed from the package and melted in a double boiler. Then it must be immediately cast in the shape needed, because TNT, when melted, becomes fluid and hardens quickly.

Caution: **Only those who are well-informed on the characteristics and reaction of molten TNT should attempt this.** If allowed to boil or crystallize, it becomes supersensitive and detonates at a small amount of shock or exposure to flame.

c. Detonation. TNT may be detonated by military electric and nonelectric blasting caps.

8. Tetrytol

a. M1 Chain Demolition Block.

(1) *Characteristics* (fig. 2).

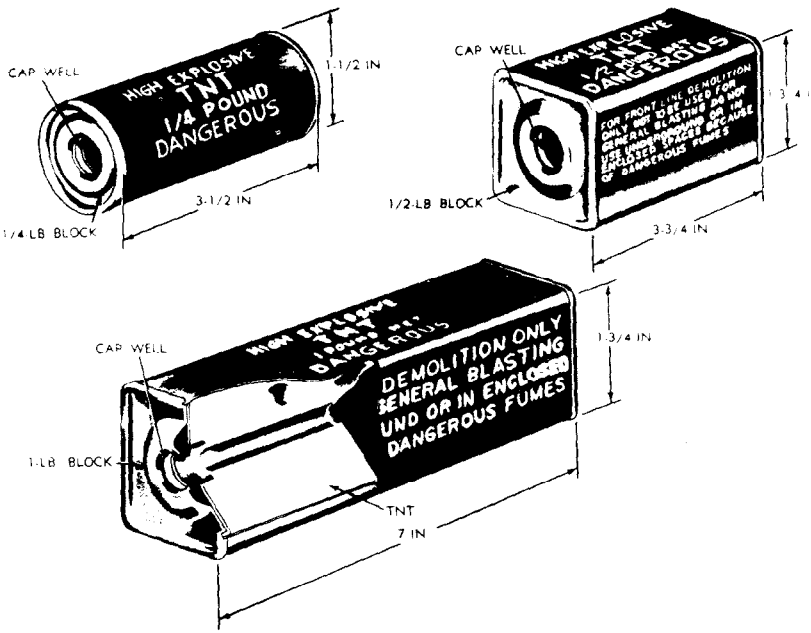


Figure 1. TNT blocks.

Case	Color	Size	Weight	Detonating velocity	Relative effectiveness
Asphalt—impregnated paper wrapper.	OD	11 x 2 x 2 in	2½ lb	23,000 fps	1.20

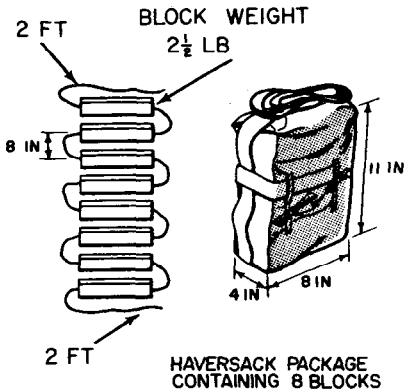


Figure 2. M1 chain demolition block.

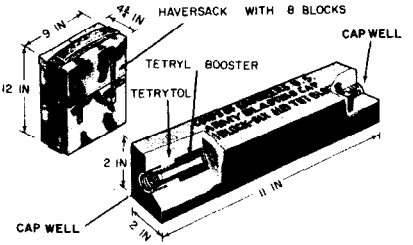


Figure 3. M2 demolition block.

Water resistance	Low temperature effects	Booster	Packaging
Excellent (only slightly soluble).	Less sensitive to shock and slight decrease in strength. Cut ends of detonating cord should be waterproofed to prevent penetration by moisture.	Tetryl pellet cast into block near each end.	Blocks are cast 8 in apart on detonating cord, with 24 in left free at each end of chain (total 192 in). One chain (8 blocks) packed in OD haversack, 11 x 8 x 4 in weighing 20.2 lb and two chains in haversacks in a wooden box.

(2) *Use.* The M1 chain demolition block may be used as an alternate to TNT. The complete chain, or any part of the chain, may be laid out in a line, wrapped around a target, or used in the haversack as it is packed. The entire chain will detonate, even though the blocks may not be in contact with each other. If less than eight blocks are needed, the required number is cut from the chain. Tetrytol is now being eliminated. When present stocks are exhausted, no more will be procured.

(3) *Detonation.* Tetrytol is detonated by means of the military electric or nonelectric blasting cap. The explosive end of the cap should extend toward the charge.

b. M2 Demolition Block.

(1) *Characteristics* (fig. 3).

Case	Color	Size	Weight	Detonating velocity
Asphalt-impregnated paper wrapper. Has threaded cap well.	OD	11 x 2 x 2 in.	2½ lb.	23,000 fps

Relative effectiveness	Water resistance	Low temperature effects
1.20	Excellent (only slightly soluble).	Slight decrease in strength and less sensitive to shock. Requires 6 turns of detonating cord for positive detonation; will explode or ignite under 50-calibre incendiary machine gun fire at subzero temperatures.

Booster	Packaging
Tetryl pellet cast in block surrounds cap well.	Eight blocks packed in a haversack, weighing approximately 22 lb, and two haversacks in a wooden box.

(2) *Use.* The M2 demolition block is used in the same manner as the M1 block. Tetrytol, however, is now being eliminated. No more will be issued after present stocks are exhausted.

(3) *Detonation.* The M2 demolition block may be detonated by the military electric or nonelectric blasting cap.

9. Composition C3 (M3 or M5 Demolition Block)

a. Characteristics (fig. 4).

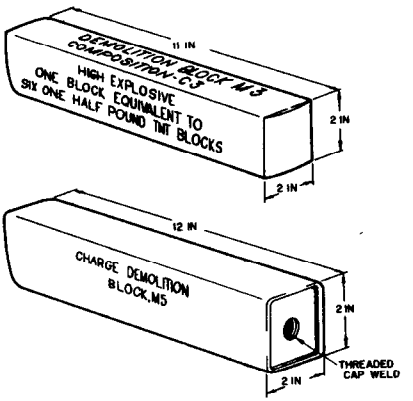


Figure 4. M3 and M5 demolition blocks.

Case	Color	Explosive color	Size
M3—Cardboard wrapper perforated for easy opening; M5—plastic container with threaded cap well.	M3—OD M5—clear plastic	Yellow odorous.	M3–11 x 2 x 2 in M5–12 x 2 x 2 in

Weight	Detonating velocity	Relative effectiveness	Water resistance
M3—2¼ lb M5—2½ lb.	25,018 fps	1.34	Good, but must be in container to prevent erosion.

Low temperature effects	Booster	Packaging	Remarks
When chilled, color changes to red; below −20°F becomes stiff and brittle; plasticity restored by heating. Velocity reduced at −20°F but still of high order.	None	M3–8 blocks packed in haversack and two haversacks in wooden box. M5—1 charge in polyethylene bag, 24 bags in wooden box.	More sensitive than TNT to initiation by impact; and odorous.

b. Use. Because of its plasticity and high detonation velocity, composition C3 is ideally suited to cutting steel structural members. It may be easily molded in close contact to irregularly shaped objects and is an excellent underwater charge if enclosed in a container to prevent erosion.

c. Detonation. Composition C3 may be detonated by the military electric or nonelectric blasting cap.

10. Composition C4

a. M5A1 Demolition Block.

(1) *Characteristics* (fig. 5).

Case	Color	Explosive color	Size
Plastic with threaded recess	Clear plastic	White	11¾ x 2 x 2 in

Weight	Detonating velocity	Relative effectiveness	Water resistance
2½ lb	26,379 fps	1.34	Excellent, if enclosed in original or improvised container to prevent erosion by stream currents.

Low temperature effects	Booster	Packaging	Remarks
Remains like putty at −70° to +170°F. Below −70°, it becomes hard and brittle.	None	One charge packed in polyethylene bag and 24 bags in wooden box.	C4 is more powerful than TNT, without the odor of C3. It is now classified standard B, to be replaced by the M112 demolition charge.

(2) *Use.* Because of its high detonation velocity and its plasticity, Composition C4 is well suited for cutting steel and timber and breaching concrete.

(3) *Detonation.* Composition C4 may be detonated by a military electric or nonelectric blasting cap.

b. M112 Demolition Charge.

(1) *Characteristics* (fig. 5).

Case	Color	Explosive color	Size	Weight	Detonating velocity	Relative effectiveness
Plastic wrapper	White	White	11 x 2 x 1 in	1¼ lb	26,379 fps	1.34

Water resistance	Low temperature effects	Packaging	Remarks
Excellent if inclosed in original or improvised container to prevent erosion by stream currents.	Remains like putty at −70°F to +170°F. Below −70° becomes hard and brittle.	30 blocks per box 14 x 11½ x 8 19/32 in; total weight 48 lb.	This is the standard C4 charge replacing the M5A1 block. Sixteen blocks will be available in the M37 demolition kit.

(2) *Use.* Because of its high detonating velocity and plasticity, the M112 demolition charge (C4) is used for cutting steel and timber and breaching concrete. It has an adhesive compound on one face for attachment to target.

(3) *Detonation.* The M112 demolition charge may be detonated by a military electric or nonelectric blasting cap.

11. M118 Demolition Charge

a. Characteristics (fig. 5).

Case	Color	Explosive color	Size	Weight	Detonating velocity
Mylar container	White	Dark green	Block: 12½ x 3¼ x 1¼ in Sheet: 12 x 3 x ¼ in.	Block: 2 lb Sheet: ½ lb	23,616 fps

Relative effectiveness	Water resistance	Low temperatures effects	Packaging
The relative effectiveness factor has not yet been established. For computing test shots, use 1.00.	Unaffected by submersion.	Retains flexibility at −65°F; does not craze or melt at +160°F.	Four sheets per package and 20 packages per box, with a volume of 1.1 cu ft. Total weight 52 lb.

Remarks. May be cut with a knife and placed in an open fire where it will burn but not explode. Will withstand impact of .30 cal. bullets fired from a distance of 40 ft. Each sheet has an adhesive compound on one face.

b. Use. After the protective cover-strip is pulled off, the sheet of explosive may be quickly pressed against any dry surface at a temperature higher than 32° F. A supplementary adhesive has been developed for colder, wet, or underwater targets. The explosive may be used in bulk or cut to accurate width and uniform thickness. It is particularly suitable for cutting steel and breaching.

c. Detonation. The M118 sheet explosive may be detonated by a military electric or nonelectric blasting cap.

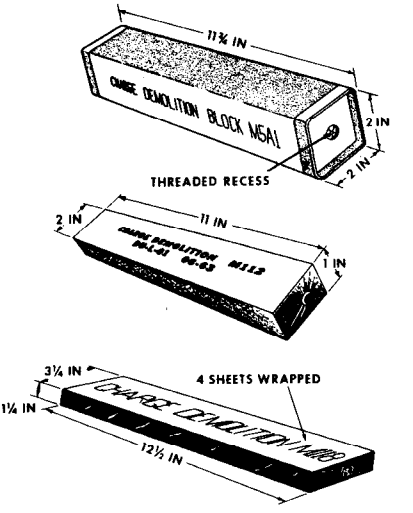


Figure 5. M5A1, M112, and M118 demolition blocks.

12. Composition B

This is a high explosive made of RDX and TNT with a relative effectiveness factor higher than that of TNT (1.35), but is more sensitive. Because of its shattering power and high rate of detonation, Composition B is used as the main charge in certain models of bangalore torpedoes and shaped charges. For further information see table VIII.

13. PETN (Pentaerythritetranitrate)

PETN, the explosive used in detonating cord, is one of the most powerful military explosives, almost equal in force to nitroglycerine and RDX. When used in detonating cord, PETN has a detonation velocity of 24,000 feet per second and is relatively insensitive to friction and shock. For further information see table VIII.

14. Amatol

Amatol is a mixture of ammonium nitrate and TNT with a relative effectiveness of 1.17. Amatol (80/20) may be found in the bangalore torpedo (table VIII).

15. RDX (Cyclonite)

RDX is the base charge in the M6 and M7 electric and nonelectric blasting caps. It is highly sensitive and brisant (great shattering effect) and the most powerful military explosive.

16. Pentolite

Pentolite is a combination of PETN and TNT used in the M2A3 shaped charge. Like Composition B it has a high rate of detonation and great shattering power.

17. Ednatol

This is a mixture of halite, or explosive H, and TNT. It has no tendency to combine with metals in the absence of moisture, and has no toxic effects. It is used in shaped charges and high explosive shells.

18. Military Dynamite, M1

a. Characteristics (fig. 6).

Wrapper	Color	Size	Weight	Detonating velocity	Relative effectiveness
Cartridge of waxed paper	Tan	8 x 1¼ in	½ lb	20,000 fps	0.92

Water resistance	Packaging	Remarks
Good	A—50 sticks in waterproofing bag, 2 bags in wooden box B—65 sticks in a carton and 2 cartons in wooden box	Contains no nitroglycerine and thus safer to store, handle, and transport than commercial dynamite. Unaffected by low temperatures.

b. Use. Very satisfactory for construction, quarrying, and many types of demolition work.

c. Detonation. Military dynamite may be detonated by means of a military electric or nonelectric blasting cap, and detonating cord (fig. 79).

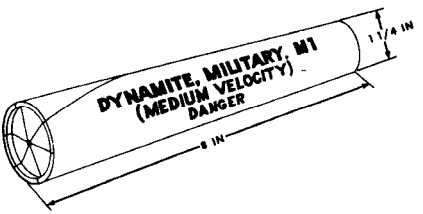


Figure 6. Military dynamite.

19. Commercial Dynamites

a. Introduction. Commercial types of dynamite are straight, ammonia, gelatin, and ammonia-gelatin. Straight dynamites are named according to the percentage of weight of nitroglycerine they contain; for example, 40 percent straight dynamite contains 40 percent nitroglycerine. Ammonia dynamite is different, however, as 40 percent ammonia dynamite indicates that the dynamite is equivalent to 40 percent straight dynamite but not that it contains 40 percent nitroglycerine by weight.

(1) Gelatin dynamite is a plastic dynamite with an explosive base of nitrocotton dissolved in nitroglycerine and is relatively insoluble in water.

(2) Ammonia-gelatin dynamite is a plastic dynamite with an explosive base of nitrocotton dissolved in nitroglycerine with ammonium nitrate added. It is suitable for underwater use.

b. Characteristics.

Wrapper	Color	Size	Weight	Composition
Paraffin-treated paper cartridge.	Tan	8 x 1¼ in	½ lb	Straight—nitroglycerine and nonexplosive filler. Ammonia—ammonium nitrate and nitroglycerine. Gelatin—nitrocotton dissolved in nitroglycerine. Ammonia-gelatin—same as gelatin with ammonium nitrate added.

	Detonating velocity	Relative effectiveness	Water resistance
Straight	40 %—15,000 fps	0.65	Good if fired within 24 hours
	50 %—18,000 fps	0.79	
	60 %—19,000 fps	0.83	
Ammonia	40 %— 8,900 fps	0.41	Poor
	50 %—11,000 fps	0.46	
	60 %—12,000 fps	0.53	
Gelatin	40 %— 7,900 fps	0.42	
	50 %— 8,900 fps	0.47	Good
	60 %—16,000 fps	0.76	
Ammonia-gelatin	40 %—16,000 fps	---	
	50 %—18,700 fps	---	Excellent

Remarks
Requires careful handling, as flames, sparks, friction, and sharp blows may cause detonation, and special care in storage, as it deteriorates rapidly. It is thus undesirable for military use.

c. Uses. Being sensitive to shock and friction, commercial dynamite is not generally used in forward areas; but it is acceptable in emergencies when other more suitable explosives are lacking. Sixty percent straight dynamite, of less strength than TNT, has a variety of uses; gelatin dynamite is applicable to underwater demolitions and to land clearing, cratering, and quarrying. A gelatin dynamite of low heaving force and a high rate of detonation is used for blasting hard rock.

d. Detonation. Commercial dynamites may be exploded when primed with a commercial No. 6 or larger, blasting cap, a military electric or nonelectric blasting cap, or detonating cord (fig. 79).

e. Low Temperature Effects. The sensitivity of dynamite decreases at diminishing temperatures until the dynamite freezes, after which it becomes extremely sensitive. Gelatin dynamite does not freeze as easily as straight dynamite. When straight dynamite is stored, the nitroglycerine tends to settle out of the sticks; accordingly, straight dynamite cases should be frequently and regularly turned until freezing sets in. Frozen dynamite may be thawed in a kettle as described in *g*, below.

f. Old Dynamite. Old dynamite may be recognized by the oily substance collected on the casing or by stains appearing on the wooden packing case. These are caused by the separation of the nitroglycerine from the porous base. Dynamite in this state, being extremely sensitive, must not be used but destroyed immediately by burning (TM 9–1300–206).

g. Frozen Dynamite. Frozen dynamite is recognized by its hardness and by the appearance of crystals (which are extremely sensitive) in the contents of the stick. Its use is not recommended. It may be destroyed by burning in the same manner as old dynamite. Frozen dynamite, may be used, however, if thawed as follows:

(1) Use a commercial thawing kettle. If this is not available, a 5- and a 10-gallon container may be combined to make a good substitute.
   (*a*) Heat water in a separate container to a temperature as high as can be tolerated by the hand.
   (*b*) Pour the heated water into the water compartment of the thawing kettle (10 gallon can).
   (*c*) Lay the frozen dynamite in the inner compartment (5-gallon container) in a horizontal position, with the bottom sticks supported on strips of wood or other material, so that the air can circulate readily around the sticks.
   (*d*) Place the kettle in a barrel or box insulated by hay or some other satisfactory material.
   (*e*) Thaw no more than 50 pounds of frozen dynamite in a single lot.
   (*f*) Never place the frozen dynamite in the thawing compartment of the kettle before the hot water is poured into the water compartment.
   (*g*) Never set the kettle over heat after the dynamite has been placed in it.
(2) Frozen dynamite is completely thawed when it has returned to its original consistency. This can be determined by squeezing the sticks lightly with thumb and forefinger. If no hard spots remain and when unwrapped no crystals are seen, it is thawed and ready for use.

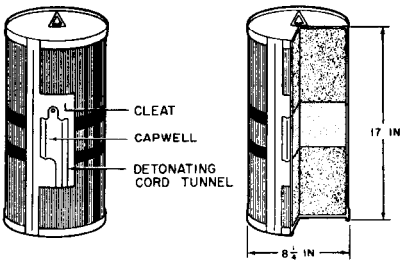
20. Foreign Explosives

a. Types. Explosives used by foreign countries include TNT, picric acid, and guncotton. Picric acid has characteristics like TNT except that it corrodes metals and thus forms extremely sensitive compounds. A picric acid explosive in a rusted or corroded container must not be used; in fact, it should not be handled in any way, except to move it very carefully to a safe disposal area or location for destruction (app C).

b. Uses. Explosives of allied nations and those captured from the enemy may be used to supplement standard supplies. Such explosives, however, should be used only by experienced soldiers and then only according to instructions and directives issued by theater commanders. Captured bombs, propellants, and other devices may be used with U. S. military explosives for larger demolition projects, such as pier, bridge, tunnel, and airfield destruction (app C). Most foreign explosive blocks have cap wells large enough to receive U. S. military blasting caps. These blasting caps, when used to detonate foreign explosives, should be test fired to determine their adequacy before extensive use.

21. Ammonium Nitrate

a. Characteristics (fig. 7).



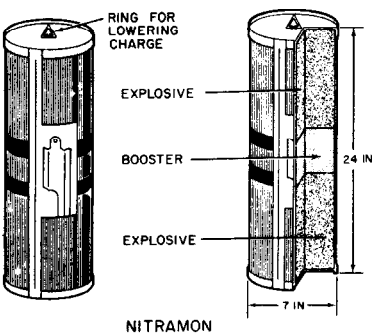


Figure 7. Ammonium nitrate and nitramon cratering charge.

Container	Color	Size	Weight of charge	Detonating velocity	Relative effectiveness
Cylindrical metal	OD	17 x 8¼ in	11,000 fps	40 lb	0.42

Water resistance	Low temperature effects	Booster
Poor. Should not be removed from container in cratering because of moisture absorption.	Slight loss in strength but functions satisfactorily.	TNT surrounding the cap well.

Packaging	Remarks
One charge is packed in wooden box 22½ x 9½ x 9¾ in. Total wt 50.8 lb.	Container has ring on top for handling and lowering into boreholes.

b. Uses. Having a low detonating velocity (11,000 fps) and thus a low shattering power that produces a pushing or heaving effect, ammonium nitrate is used chiefly as a cratering charge. It is also effective in ditching.

c. Detonation. The container has a cap well

and a detonating cord tunnel for priming. A cleat is placed above and to the side of the cap well for attaching electric and nonelectric primers. Frequently a primed one-pound block of TNT is placed on the charge to insure detonation.

22. Nitramon Cratering Charge

a. Characteristics (fig. 7).

Container	Color	Size
Cylindrical metal.	OD	24 x 7 in

Weight of charge	Detonating velocity	Relative effectiveness
40 lb	11,000 fps	0.42

Water resistance	Low temperature effects
Poor. Should not be removed from the metal container in cratering because of moisture absorption.	Slight loss in strength but functions satisfactorily.

Booster	Packaging
TNT surrounding the cap well.	One metal container in wooden box 27½ x 8⅞ x 9¾ in. Total weight 52 lb.

b. Use. Because of the low detonating velocity (11,000 fps) and low shattering power that produces a heaving effect, this charge is very effective in cratering and ditching. The container has a ring on top for general handling and lowering into boreholes.

c. Detonation. The container is fitted with a cap well and a tunnel for priming and a cleat to attach electric and nonelectric primers. A primed 1-pound block of TNT is placed on the charge for positive detonation.

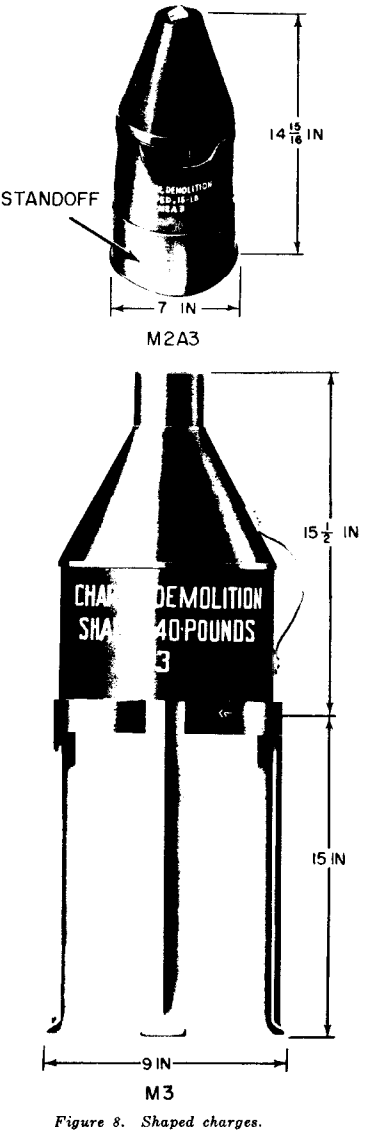


Figure 8. Shaped charges.

23. Shaped Charges

A shaped charge is an explosive charge with its detonating action directed to increase its effectiveness in penetrating steel, armor, and concrete and other masonry (fig. 8). Charges, as issued, are usually cylindrical in shape but may be linear like the charges included in the M157 demolition kit (para 27c). Cylindrical shaped charges have a conical top, a conical recess, and a metal or glass liner in the base. The threaded cap well in the top is for priming with military electric or nonelectric blasting caps. Shaped charges, generally, are made from such explosives as Composition B, pentolite, and ednatol.

a. M2A3 and M2A4 Shaped Charges.

(1) *Characteristics* (fig. 8).

Case	Color	Weight of charge	Size	Explosive	Booster
Water resistant fiber	OD	12 lb	14 15/16 x 7 in	50/50 pentolite or composition B.	M2A3: 50/50 pentolite with comp B explosive. M2A4: Comp A3, resistant to small arms fire.

Liner	Low temperature effects	Packing	Remarks
Glass	Satisfactory in arctic climates.	Three charges packed in wooden box 33⅛ x 10⅜ x 9½ in. Total weight 66 lb.	Both models have a cardboard cylindrical standoff fitted to the case.

(2) *Use.* Shaped charges are used primarily to bore holes in earth, metal, masonry, concrete, and paved and unpaved roads. Their effectiveness depends largely on their shape and the material of which they are made, the explosive, and proper placement. The penetrating capabilities in various materials and proper standoff distances are given in table XII.

(3) *Detonation.* The M2A3 and M2A4 shaped charges contain a threaded cap well for detonation by electric and nonelectric blasting caps. Dual priming, however, is extremely difficult because of the configuration of the case and the need for priming at the exact rear-center. They are not effective under water because of the obstruction to the jet.

b. M3 Shaped Charge.

(1) *Characteristics* (fig. 8).

Case	Color	Weight of charge	Size	Explosive	Booster
Metal	OD	30 lb	15½ x 9 in (less standoff).	50/50 pentolite or composition B.	50/50 pentolite with comp B charge.

Liner	Low temperature effects	Packaging	Remarks
Steel or copper	Satisfactory in arctic climates.	One each in wooden box 20½ x 13⅜ x 11¾ in. Total weight 65 lb.	Provided with metal tripod standoff 15 in high.

(2) *Use.* Shaped charges, primarily, are used to bore holes in earth, metal, masonry, pavement and the like. Effectiveness depends considerably on the shape and material in the cone, the explosive used, and proper placement. The penetrating effects of shaped charges in various materials and relative standoff distances are given in table XII.

(3) *Detonation.* The M3 shaped charge is provided with a threaded cap well for detonation by electric and nonelectric blasting caps. Dual priming is very difficult because of the slope of the case and the need for exact rear-center priming. The M3 shaped charge is not effective under water because of the obstruction to the jet.

c. Special Precautions. In order to achieve the maximum effectiveness of shaped charges—

(1) Center the charge over the target point.

(2) Set the axis of the charge in line with the direction of the hole.

(3) Use the pedestal provided to obtain the proper standoff distance.

(4) Be certain that there is no obstruction in the cavity liner or between the charge and the target.

(5) Be certain that soldiers using shaped charges in the open are at least 900 feet away in defilade under cover, or at least 300 feet away if in a missileproof shelter, before firing.

24. M1A1 and M1A2 Bangalore Torpedo Kits

a. Characteristics (fig. 9).

Case	Color	Components	Section weight	Section dimensions	Explosive
Metal	OD	10 loading assemblies or sections; 10 connecting sleeves; one nose sleeve.	Approx 13 lb	5 ft x 2 ⅛ in	M1A1—approx 9 lb amatol and TNT booster; M1A2—approx 9 lb comp B and comp A3 booster.

Packaging	Remarks
One kit packed in wooden box 64⅛ x 13⅜ x 7⅛ in. Total weight 176 lb.	Four inches of length at both ends of each section contains a booster.

b. Assembly for Use. All sections have a threaded cap well at each end so that they may be assembled in any order. The connecting sleeves make rigid joints. A nose sleeve is placed on the front of the torpedo to assist in pushing it through entanglements and across the ground. It is also desirable to attach an improvised loading section without explosive on the end to forestall premature detonation by a mine when the torpedo is shoved into place. In the assembly of two or more tubes, the nose sleeve is pressed onto one end of one tube, and the other end is connected to a second tube by a connecting sleeve. A bangalore torpedo or torpedo section may be improvised by the use of a 2-inch diameter pipe with a 24-gage wall thickness with approximately 2 pounds of explosive per foot of length. Successive pipe lengths, however, must be closely connected.

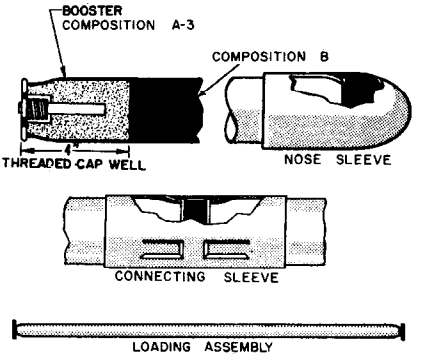


Figure 9. M1A1 bangalore torpedo.

c. Use. The bangalore torpedo clears a path 10 to 15 feet wide through barbed wire entanglements. In minefield breaching, it will explode all antipersonnel mines and most of the antitank mines in a narrow foot path. Many of the mines at the sides however may be shocked into a sensitive state, which makes extreme care necessary in any further mineclearing. Bangalore torpedoes also may be used in bundles as substitute explosive charges in the M3A1 antitank mineclearing projected charge demolition kit (fig. 13).

d. Detonation. The military electric or nonelectric blasting caps will detonate the bangalore torpedo. In obstacle clearance, the bangalore torpedo should be primed after it has been placed. The cap well at the end should be protected with tape or a wooden plug while the torpedo is being pushed into place. Priming is generally done either by means of priming adapter and a military electric or nonelectric blasting cap and time fuse, or by detonating cord with six turns around the 4-inch booster portion of the torpedo.

25. M37 Demolition Charge Assembly

The M37 charge assembly (fig. 10) consists of eight M5A1 demolition blocks, eight demolition block hook assemblies, and two M15 priming assemblies. The demolition blocks are packed in two bags, four blocks per bag, and the assembly placed in an M85 carrying case. The M15 priming assembly is a 5-foot length of detonating cord with two plastic adapters and two RDX boosters attached. The adapters are threaded to fit the standard cap well in the demolition block. The priming assembly has two detonating cord clips for fixing the M37 charge assembly to the main line. The hook assemblies are hooks and pieces of rope for attaching charges to the target.

a. Use. This assembly is applicable to the use of assault demolition teams in the reduction of obstacles. It is very effective against small dragon's teeth approximately 3 feet high and 3 feet wide at the base.

b. Detonation. The M37 demolition charge is detonated by means of the M15 priming assembly and an electric or nonelectric blasting cap or by a ring main attached by means of the detonating cord clips provided.

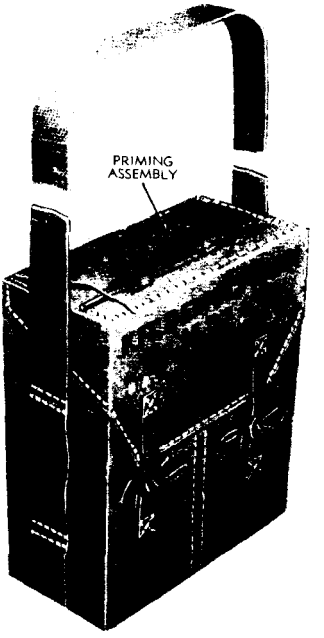


Figure 10. M37 demolition charge assembly.

c. Packaging. One assembly is packed in an M85 carrying case, and two are packed in a wooden box 17⅛ x 11½ x 12½ inches. The gross package weight is 57 pounds.

26. Rocket-Propelled Train Bangalore Torpedo (Barney Google)

The device consists of 20 sections of bangalore torpedo fitted together by special connecting sleeves to form a 100-foot train (fig. 11). A kit contains the rocket motor, tail assemblies, and couplings for 20 sections. The motor is fitted to the front of the train to provide propulsion. Detonation occurs at the tail assembly by means of a nonelectric blasting cap, pull fuze, and a reel of cable.

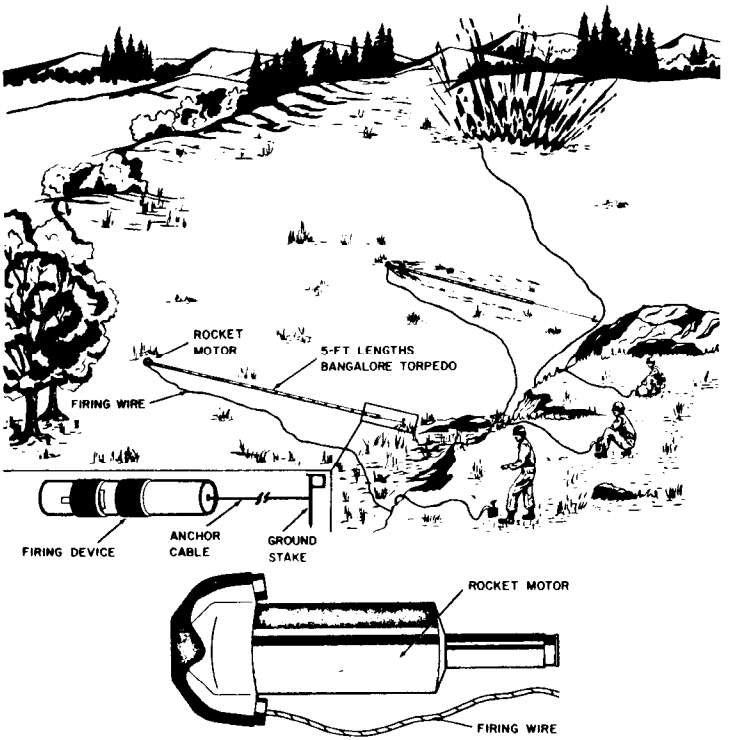


Figure 11. Rocket-propelled bangalore torpedo (Barney Google).

a. Uses. The rocket-propelled bangalore torpedo is used against barbed wire entanglements, antipersonnel mines, and similar small obstacles. The rocket propulsion enables deeper penetration of small obstacles with less exposure of friendly soldiers to enemy observation and fire.

b. Detonation. The assembled torpedo is placed at a spot within range of the target. The 400-foot reel of cable is shortened to the proper length and its free end is anchored firmly. After the safety has been unscrewed from the tail assembly and all soldiers have taken cover, the rocket motor is fired electrically. After the torpedo has traveled a distance equal to the length of the anchored cable, the pull fuze is actuated and the assembly detonated.

27. Projected Charge Demolition Kits

a. M1 and M1E1. These are identical in all respects except for the delay detonators and the time blasting fuze igniters issued with them. The M1E1 has the M60 weatherproof blasting fuse igniter and the 15-second delay M1A2 percussion detonator, while the M1 has the M2

weatherproof blasting fuse igniter and the 15-second delay M1 or M1A1 friction detonator (fig. 12).

(1) *Components.* These are a nylon-covered detonating cable, propulsion unit, launcher, fuse lighter, delay detonator, anchor stake, and carrying case. The explosive item, or detonating cable, is 1 inch in diameter and approximately 170 feet (52 meters) long; it weighs 63 pounds, 46 pounds of which is oil-soaked PETN. The detonating cable is composed of 19 strands of special detonating cord, each containing 100 grains of PETN per foot. This differs from the regular (reinforced) detonating cord, which contains only 50 to 60 grains of PETN per foot. Regular detonating cord cannot be used as a substitute in the kit.

(2) *Use.* This kit is emplaced to project and detonate a cable across a pressure-actuated antipersonnel minefield. Grass, leaves, other light vegetation, and some soil are blown aside in a lane about 8 feet wide. More soil is blasted aside when the ground is moist and soft than when it is dry and hard. Camouflaged antipersonnel mines and those near the surface in the 8 foot lane are usually exposed.

(3) *Detonation.* One soldier fires the complete assembly. First the kit is emplaced; then the fuse lighter on the jet propulsion unit is pulled. The 15-second delay in the propulsion fuse allows the soldier to move the 5-foot distance from the launcher to the anchor stake and pull the fuse lighter safety pin and pull ring on the detonating cable (which also has a 15-second delay) and then take cover at least 100 feet behind the assembly.

(4) *Packaging.* The complete assembly is issued in a OD-colored waterproof aluminum carrying case. Each case is packed in a wooden box 25½ x 18⅜ x 19¼ inches. The gross weight of the kit and box is 142 pounds.

b. Antitank Mine-Clearing Kits. These kits,

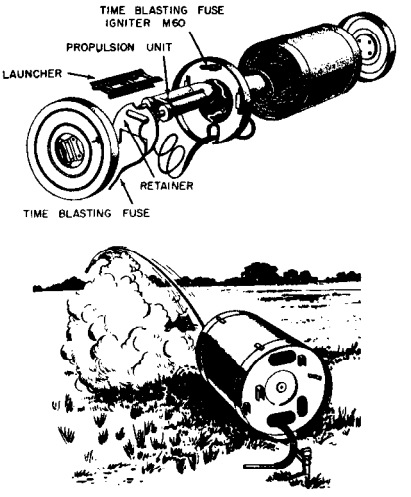


Figure 12. M1E1 projected charge kit.

the M2, M2A1, M3, and M3A1, consist of semi-rigid projected charges and the accessories and tools needed to assemble and attach them to a light or medium tank. They are approximately 14 inches wide, 5 inches high, and 400 feet (121.9 meters) long, weighing approximately 9,000 pounds, including 4,500 pounds of explosive. They are supplied in elliptically-shaped units or elements 5 feet long, containing about 35 pounds of explosive. The M3 consists of an 80/20 amatol charge and a 6-inch crystalline TNT booster at each end. The M3A1 (fig. 13 and table I) consists of Composition B charge with a Composition A–3 booster in each end. Bangalore torpedo explosive elements may be substituted for the standard explosive elements, four for each. Both are initiated by two bullet-impact fuses by fire from the main tank armament or from any 37mm or larger high explosive shell with a super-quick fuse. Both types have a threaded cap well suitable for a standard firing device and an electric or non-electric military blasting cap. This cap well also makes possible the use of the explosive ele-

ment as a separate expedient charge. In most soils, these charges form a crater about 100 meters (330 feet) long, 5 meters (16 feet) wide, and 2 meters (7 feet) deep.

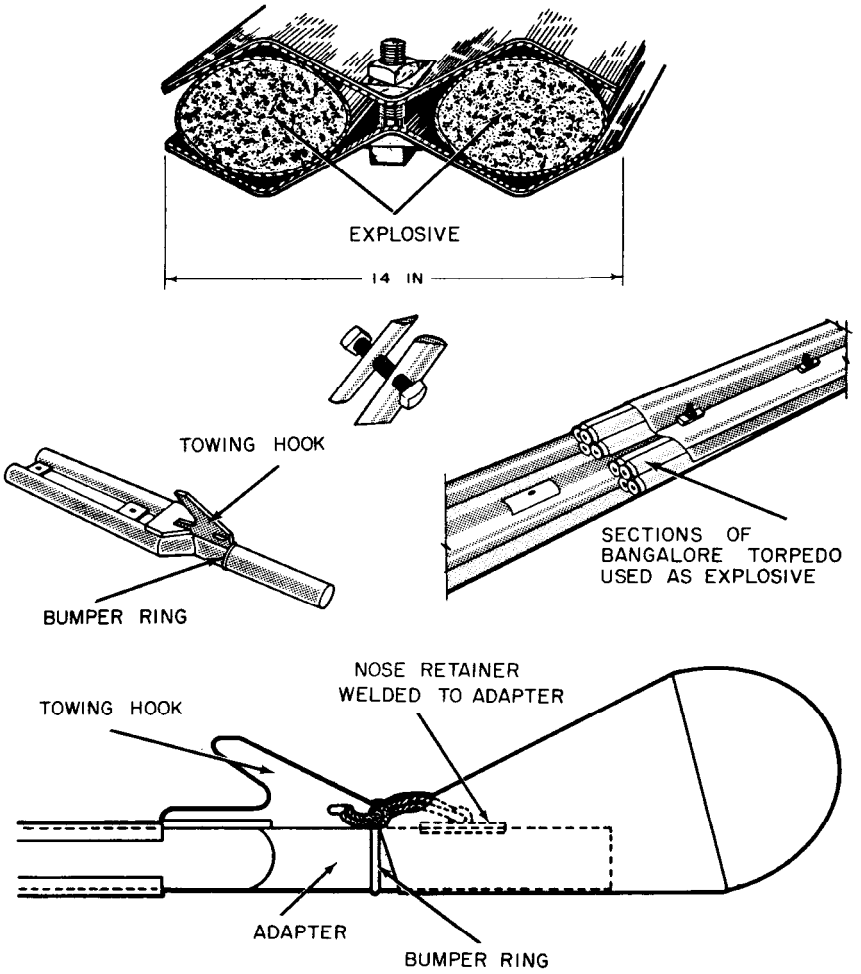


Figure 13. M5A1 projected charge kit.

Table I. Comparison of M2, M2A1, M3, and M3A1 Projected Charge Demolition Kits

	M2	M2A1	M3 and M3A1
Total net weight	12,500 lb	15,000 lb	9000 lb
Corrugated plates	Steel, 53 lb, 164	Steel, 53 lb, 172	Aluminum, 16 lb, 200
Washers	1 per bolt, 2 in long	1 per bolt, 2 in long	2 per bolt, 4 in long
Nose	Steel, two piece, bolted; held to adapter by bolt.	Steel, two piece, bolted; held to adapter by special retainer.	Aluminum, one piece, welded; held to adapter by special retainer.
Tamping bags	Paper	Paper	Cloth or paper
Pushing attachment	Wire rope	Steel chain	Steel chain
Total explosive	3200 lb	4500 lb	4500 lb
Explosive cartridges	4 feet long, 20 lb explosives; steel casing; circular in cross section.	5 feet long, 35 lb explosives; aluminum casing; elliptical in cross section.	5 feet long, 35 lb explosives; aluminum casing; elliptical in cross section.
Fuze and shield	1 of each	2 of each	2 of each
Towing assembly rigging.	Rope on towing yoke raised by hand.	M2 fittings and rigging improved and strengthened; cable on towing yoke raised by winch on periscope fitting.	M2 fittings and rigging improved and strengthened; cable on towing yoke raised by winch on periscope fitting.

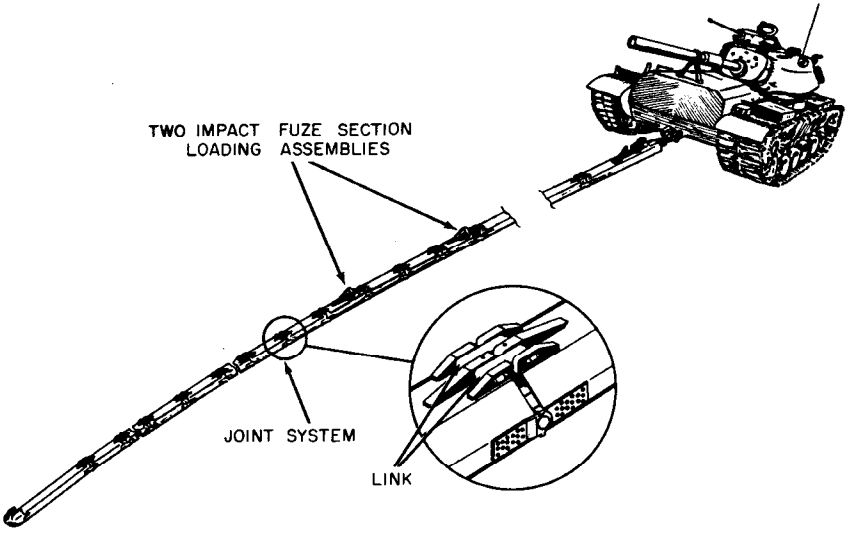


Figure 14. M—157 projected demolition charge kit.

c. M–157.

(1) *Description.* This kit (fig. 14) measures about 12 inches in width, 7 inches in height, and 400 feet (121.9 meters) in length. It consists of 79 sections —1 nose section, 13 body sections, 62 center-loading sections, 2 impact fuse sections, and 1 tail section. Only 64 of the 79 sections contain explosives— the 62 center loading sections and the 2 impact fuse sections. The kit weighs 11,000 pounds including approximately 3,200 pounds of explosive. The explosive is a linear shaped charge, 12 inches wide, 7 inches high, and 5 feet long, containing approximately 45 pounds of Composition B and 5 pounds of Composition C–4. As the insert tubes are welded to the walls of the center loading sections, the explosive elements cannot be used as separate charges or replaced by any substitute item in the field. The linear shaped charge insures a wider, clearer path throughout minefields than many other explosive clearing devices. In most soils this charge forms a crater about 100 meters (330 feet) long, 4 to 5 meters (12 to 16 feet) wide, and 1 to 1½ meters (3 to 5 feet) deep.

(2) *Use.* Projected demolition charges are used chiefly in the deliberate breaching of minefields. They are also effective against bands of log posts, steel rail posts, antitank ditches, and small concrete obstacles. These charges are adequate to break down the sides of an antitank ditch. They will also clear a path through the ditch adequate for tank traffic, if it is unrevetted and 5 feet deep or less and if the charges project beyond the far side of the ditch. They are effective in ditches from 5 to 8 feet deep if the soil is very favorable. The explosive elements of the M3 and M3A1 projected charges may be used as expedient individual charges in the M–157 kit.

(3) *Detonation.* The charges are generally detonated from a tank by means of bullet impact fuse, which has a target plate that bears on the firing pin and is held in place by a shear pin and a safety fork that must be removed before the fuse can be actuated. The fuse is detonated by fire from the main tank armament or from any 37mm or larger high explosive shell with a super-quick fuse. Two fuses are provided to insure that one is visible to the tank gunner at all times.

28. Improvised Charges

Demolition teams operating in the field frequently find targets to which standard methods and charges may not apply and improvisations are required. Frequently the success of the mission depends upon the ingenuity or the team. The package and pole charges are such improvisations. By skillful modifications they may be applied successfully in many situations.

a. Package Charges. Charges prepared in convenient packages of appropriate size and shape are always more readily put in place than other types. Explosives may be packaged in sandbags to make elongated cylindrical charges for boreholes. Blocks of TNT or other explosives may be stacked together and bound with tape or twine or wrapped in canvas, other cloth, or paper. A satchel charge may be improvised by tying or taping explosive blocks to a board with a handle attached. Large charges may consist of an entire case of explosives. Here at least one block or one cartridge is removed from the case, primed, and replaced. A still larger charge may be made by lashing several cases of explosive together. The detonation of a single primer will fire the entire charge. Dual priming systems, however, should be used if possible.

b. Pole Charges. Pole charges are convenient for placement against pill boxes, hard-to-reach bridge stringers, underwater bridge supports, and other locations not easily accessible. Pole charges are usually an assembly of an explosive charge; detonating cord; fuse lighter, time fuse, nonelectric blasting cap; and a pole for placing or propping them in position. Pole charges are usually prepared in the same manner as package charges. Dual priming should be used, if possible.

Section III. DEMOLITION ACCESSORIES

29. Time Blasting Fuse

Time blasting fuse transmits a flame from a match or igniter to a nonelectric blasting cap or other explosive charge, providing a time delay wherein blasters may retire to a safe distance prior to the explosion. There are two types: safety fuse and time fuse M700. These may be used interchangeably.

a. Safety Fuse. Safety fuse is limited standard. It is used in general demolitions. It consists of black powder tightly wrapped with several layers of fiber and waterproofing material and may be any color, orange being the most common (fig. 15). As the burning rate may vary for the same or different rolls from 30 to 45 seconds per foot under different atmospheric and climatic conditions (exposure for over 12 hours to the elements, extreme changes in temperature, and the like), each roll must be tested prior to using in the area where the charge is to be placed. Particular precautions must be taken if used under water, as the rate of burning is increased significantly. Accordingly, each roll should be tested under water prior to preparation of the charge. In arctic temperatures, the outside covering becomes brittle and cracks easily.

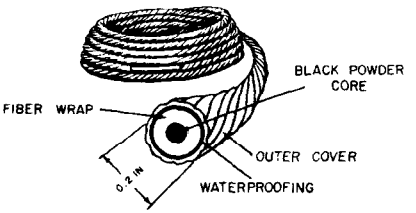


Figure 15. Safety fuse.

b. Time Fuse M700. This fuse (fig. 16) is similar to safety fuse and may be used interchangeably with it. The fuse is a dark green cord 0.2 inches in diameter with a plastic cover, either smooth or with single painted bands around the outside at 1-foot or 18-inch intervals and double painted bands at 5-foot or 90-inch intervals, depending on the time of manufacture. These bands are provided for easy measuring purposes. The burning rate is approximately 40 seconds per foot, which permits the soldier firing the charge to reach a place of safety. The burning rate, however, must always be tested in the same manner as that of safety fuse, above. At arctic temperatures, the outside covering becomes brittle and cracks easily.

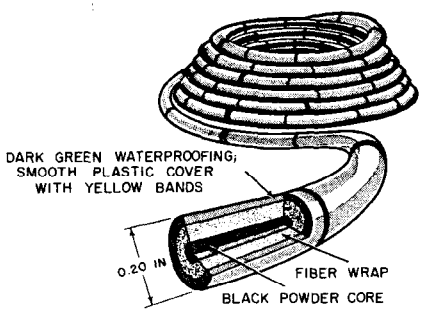


Figure 16. Time fuse M700.

c. Packaging.

(1) *Safety fuse.*

(*a*) 50-foot coil, 2 coils per package, and 30 packages (3000 feet) in a wooden box 24¾ x 15¾ x 12½ inches. The total package weight is 71.8 pounds.

(*b*) 50-foot coil, 2 coils per package, 5 packages sealed in a metal can, and 8 cans (4000 feet) per wooden box 30 x 14⅝ x 14⅝ inches. The total package weight is 93.6 pounds.

(*c*) 50-foot coil, 2 coils per package, and 60 packages (6000 feet) per wooden box 29 x 22 x 17 inches. The total package weight is 162 pounds.

(2) *Time fuse M700.* This is packed in 50-foot coils, 2 coils per package, 5 packages per sealed container, and 8 containers (4000 feet) per wooden box 30⅛ x 15⅛ x 14⅞ inches. The total package weight is 94 pounds.

30. Detonating Cord

a. Characteristics. Detonating cord consists of a core of PETN in a textile tube coated with a layer of asphalt. On top of this is an outer textile cover finished with a wax gum composition or plastic coating (fig. 17). It will transmit a detonating wave from one point to another at a rate of at least 5900 meters per second or about 19400 feet. Partially submerged water-soaked detonating cord will detonate if initiated from a dry end. Although it does not lose its explosive properties by exposure to low temperatures, the covering, becoming stiff, cracks when bent. Thus great care is required in using detonating cord primers in arctic conditions. Data on the types available is shown in table II.

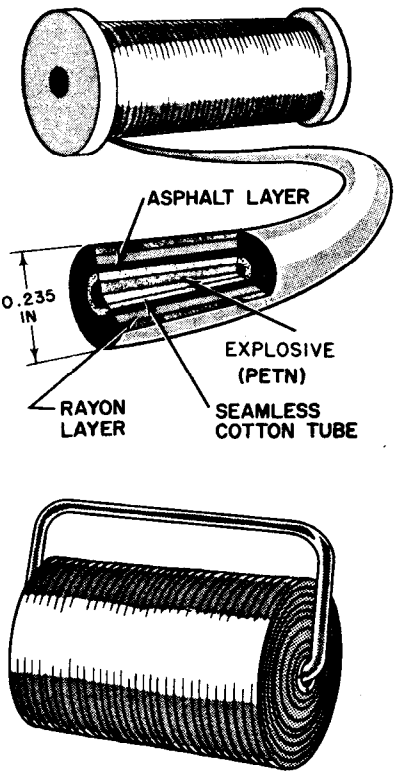


Figure 17. Reinforced pliofilm-wrapped detonating cord.

Table II. Detonating Cord Data

Nomenclature	Nom. dia. (in.)	Covering	Loading	Packing				Weight (lbs.)
				Description	Dimension (Inches)			
					Length	Width	Height	
CORD, DETONATING: fuse, primacord (PETN) Type I*.	0.210	Cotton with wax gum composition finish.	50 grn PETN/ft.	1. 1,000 ft/spool, 1 spool (1,000 ft)/wdn bx	10⅛	10	10	16
				2. 100 ft/spool, 25 spool (2,500 ft)/wdn bx	19¾	18½	8½	46
				3. 500 ft/spool, 1 spool/sealed can, 8 can (4,000 ft)/wdn bx	30	15	14⅝	105

Table II. Detonating Cord Data—Continued

Nomenclature	Nom. dia. (in.)	Covering	Loading	Packing				
				Description	Dimension (inches)			Weight (lbs.)
					Length	Width	Height	
				4. 500 ft/spool, 8 spool (4,000 ft)/wdn bx				
				5. 50 ft/spool, 100 spool (5,000 ft)/wdn bx	24	17	12	94
CORD, DETONATING: fuse, primacord (PETN) Type II*	0.216	Double cotton with wax gum composition finish.	50 grn PETN/ft.	100 ft/spool, 50 spool (5,000 ft)/wdn bx.	21	14¾	18⅜	111
CORD, DETONATING: fuse, primacord (PETN) (50-ft spool (spliced)).	0.210	Cotton with wax gum composition finish.	50 grn PETN/ft.	Packed as required				
CORD, DETONATING: fuse, primacord (PETN) inert.	0.210	Cotton with wax gum composition	Inert	Packed as required.				
CORD, DETONATING: reinforced, pliofilm-wrapped, waterproof, Type IV**.	0.235	Textile with plastic coating.	60 grn PETN/ft.	1. 1,000 ft/spool, 1 spool/crdbd bx, 3 bx/wtrprf lead foil env 1 env (3,000 ft)/wdn bx	33⅜	11¾	11¼	77
CORD, DETONATING: reinforced, pliofilm-wrapped, waterproof, Type IV**.				2. 500 ft/spool, 1 spool sealed can, 8 can (4,000 ft)/wdn bx				
CORD, DETONATING: reinforced, dummy.	0.235	Textile with plastic coating.	Inert	Packed as required				
CORD, DETONATING: waterproof, plastic outer covering (8-ft length) Type I**.	0.235	Textile with plastic coating.	60 grn PETN/ft.	200 length (1,600 ft)/wdn bx	26½	18	11	57

* Type designation in accordance with PA–PD–417, 7 May 1954.
** Type designation in accordance with MIL–C–17124A, 11 June 1959.

Abbreviations:

bx . . . . . box(es) dia . . . . . diameter ft . . . . . foot (feet) lb . . . . . pound(s) wdn . . . . wooden
crdbd . . . cardboard env . . . . envelope grn . . . . grain(s) nom . . . . nominal wtrprf . . . waterproof

b. Precautions in Use. The ends of detonating cord should be sealed with a waterproof sealing compound to keep out moisture when used to detonate underwater charges, or charges left in place several hours before firing. A 6-inch free end will also protect the remainder of a line from moisture for 24 hours. In priming, kinks or short bends, which may change the direction of detonation and thus cause misfires, should be avoided.

31. Blasting Caps

Blasting caps are used for initiating high explosives. They are designed for insertion in cap wells, and are also the detonating element in certain land mine firing devices. Special military blasting caps are designed to detonate the less sensitive explosives like TNT, military dynamite, and tetrytol. Commercial caps may be used to detonate more sensitive explosives like tetryl and commercial dynamite, in an emergency. Two commercial caps are required to detonate military explosives; however, there is also a priming problem as two caps will *not* fit into the standard threaded recess. Both military and commercial blasting caps, being extremely sensitive, may explode unless handled carefully. They must be protected from shock and extreme heat and not tampered with. Blasting caps must never be stored with other explosives, nor should they be carried in the same truck except in an emergency (para 141*b*(3)). Two types, electric and nonelectric, are used in military operations.

a. Electric Blasting Caps. These are used when a source of electricity, such as a blasting machine or a battery, is available. Two types are in use, military and commercial (fig. 18). Military caps are instantaneous, and the commercial, instantaneous and delay. Instantaneous caps include the M6, the special or military, and the commercial No. 6 and No. 8. No. 8 commercial delay caps (fig. 18) are issued from the first to the fourth delay ranging from 1:00 second to 1:53 seconds. When two or more of the special instantaneous caps are used, they should be of the same manufacture except for the M6 caps, which regardless of manufacturer, may be used interchangeably as they are all made to a single specification. All issue electric caps have lead wires of various lengths for connection in a circuit. The most commonly used are 12 feet long. Most all have a short circuiting shunt or tab, to prevent accidental firing, which must be removed before connection in a firing circuit. If the cap is issued without a shunt, which is sometimes the case with the M6, the bare ends of the lead wires must be twisted together to provide the shunting action. Data on electric blasting caps is shown in table III.

b. Nonelectric Blasting Caps. Nonelectric blasting caps (fig. 19) may be initiated by time blasting fuse, firing devices, and detonating cord. Because they are extremely difficult to waterproof, they should not be used with time blasting fuse to prime charges placed under water or in wet boreholes. If such be necessary, however, they should be moistureproofed with waterproof sealing compound. Those in use include the commercial No. 6 and No. 8 and the special or military types I (J–1 (PETN or RDX) and M7 (fig. 19). Special caps will detonate military explosives, and the commercial caps the more sensitive types. The latter, however, will detonate military explosives if used in pairs; but this presents a priming problem, as two caps will *not* fit into the standard threaded cap well. The M7 special caps are flared at the open end for easy insertion of the time fuse. Data on nonelectric caps is shown in table IV.

32. Priming Adapter M1A4

This is a plastic hexagonal-shaped device threaded to fit threaded cap wells and the M10 universal destructor. A shoulder inside the threaded end is large enough to accept blasting fuse and detonating cord but too small to permit passage of a blasting cap. The adapter is slotted longitudinally to permit easy and quick insertion of the electric blasting cap lead wires (fig. 20). The M1A4 replaces the M1A2 and M1A3 models, which have cylindrical bodies. The hexagonal M1A4 is more readily handled by men wearing arctic mittens.

33. Adhesive Paste, M1

This is a sticky, putty-like substances for attaching charges to vertical or overhead flat surfaces. It is useful in holding charges while

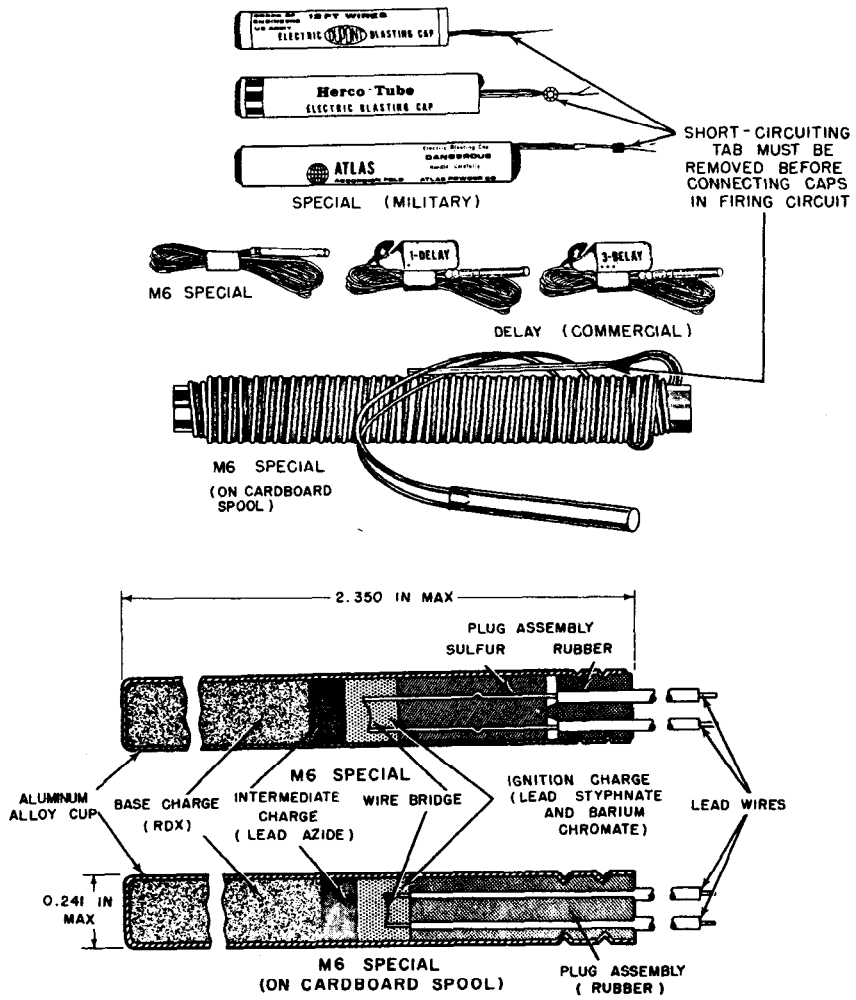


Figure 18. Electric blasting caps.

Table III. Electric Blasting Cap Characteristics

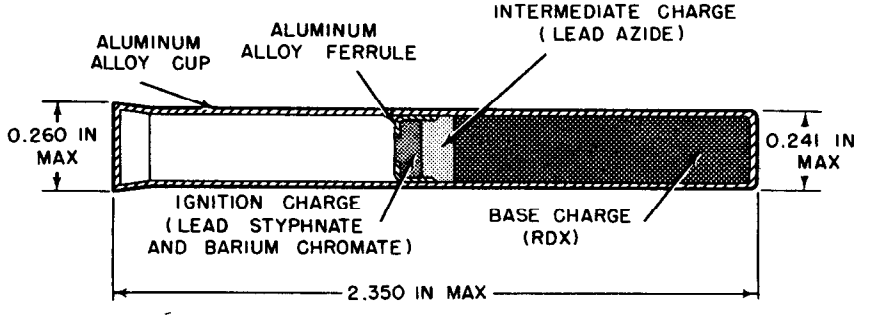
Nomenclature	Lead wire characteristics	Packing				
		Description	Dimensions (inches)			Weight (lbs.)
			Length	Width	Height	
CAP, BLASTING: commercial, electric, No 6, instantaneous	Short lead, 4 ft through 10 ft	500/wdn bx	18	13⅜	12	48.6
CAP, BLASTING: commercial, electric, No 6, instantaneous	Medium lead, 12 ft through 40 ft	As required				
CAP, BLASTING: commercial, electric, No 6, instantaneous	Long lead, 50 ft through 100 ft	As required				
CAP, BLASTING: commercial	Short lead, 4 ft through 10 ft	1. 70/ctn. 5 ctn (350 cap)/wdn bx	15	12½	6½	22.2
CAP, BLASTING: commercial electric, No 8, instantaneous	Medium lead, 12 ft through 40 ft	As required				
CAP, BLASTING: commercial electric, No 8, instantaneous	Long lead, 50 ft through 100 ft	As required				
CAP, BLASTING: electric No 8, strength	Lead 6 ft long, copper tinned	50/ctn				
CAP, BLASTING: electric, No 8, strength	Lead 6 ft long	70/ctn	13¾	7¼	4¾	8
CAP, BLASTING: electric, No 8, strength	Lead 30 ft long, copper tinned	25/ctn				
CAP, BLASTING: electric, No 8, 1st delay (approx 1.00 sec)	Lead 12 ft long	500/wdn bx	19½	13½	9¼	30
CAP, BLASTING: electric, No 8, 2nd delay (approx. 1.18 sec)	Lead 12 ft long	500/wdn bx	19½	13½	9¼	30
CAP, BLASTING: electric, No 8, 3rd delay (approx. 1.35 sec)	Lead 12 ft long	500/wdn bx	19½	13½	9¼	30.5
CAP, BLASTING: electric ,No. 8, 4th delay (approx. 1.53 sec)	Lead 12 ft long	500/wdn bx	19½	13½	9¼	30.0
CAP, BLASTING: electric, high strength	Lead 6 ft long, copper tinned	1. 50/ctn 2. 70/ctn	9 14½	4⅛ 7⅛	3 3¾	2.3 8.0
CAP, BLASTING: electric, high strength	Lead 9 ft long, copper tinned	50/ctn	7¼	4⅜	3¼	4.0
CAP, BLASTING: electric, low strength	Lead 6 ft long, copper tinned	50/ctn	6½	6	2⅞	2.0
CAP, BLASTING: electric, inert	Various long lead wires	As required				
CAP, BLASTING: special, electric	Lead 12 ft long	1. 1/chipbd pkg. 50 pkg/fbrbd bx, 10 bx (500 cap)/wdn bx 2. As required	28¼ 17½	15¼ 12½	11¾ 11	76.5 51.0

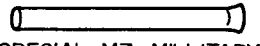
Table III. Electric Blasting Cap Characteristics—Continued

Nomenclature	Lead wire characteristics	Packing				
		Description	Dimensions (inches)			Weight (lbs.)
			Length	Width	Height	
CAP, BLASTING: special, electric, M6	Lead 12 ft long, copper tinned	1/crdbd spool, 6 spool/ctn, 1 ctn/ water-prf bg, 25 bg/fbrbd bx, 6 fbrbd bx (900 cap)				

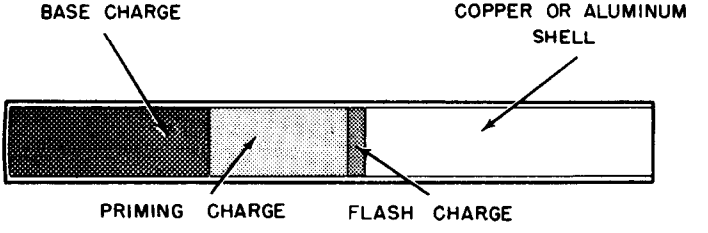
Abbreviations:

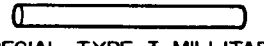
bg . . . . . bag(s)
bx . . . . . box(s)
chipbd . . . chipboard
crdbd . . . . cardboard
ctn . . . . . carton(s)
fbrbd . . . . fiberboard
ft . . . . . foot(feet)
lb . . . . . .pound(s)





SPECIAL M7 MILLITARY





SPECIAL TYPE I MILLITARY

Figure 19. Military nonelectric blasting caps.

Table IV. Nonelectric Blasting Cap Characteristics

Nomenclature	Packing				
	Description	Dimensions (inches)			Weight (lbs.)
		Length	Width	Height	
CAP, BLASTING: nonelectric, No 6, instantaneous.	1. 5,000/wdn bx 2. 100/ctn, 10ctn/fbrbd bx, 1 bx/wtrprf bag, 5 bag (5,000 cap)/wdn bx	20⅛	9⅞	8¾	29
CAP, BLASTING: nonelectric, No 8, instantaneous.	1. 100/ctn, 50 ctn (5,000 cap)/wdn bx 2. As required	18⅛	13	7¾	50
CAP, BLASTING: special, nonelectric (Type I(J-1)) (PETN or RDX).	1. 50/mtl can, 20 can/fbrbd ctn, 5 ctn (5,000 cap)/wdn bx 2. 100/ctn, 10 ctn/crdbd bx, 10 bx (10,000 cap)/inner wtrprf pkg, 1 inner pkg in sawdust/outer wtrprf pkg/wdn bx 3. As required	24¾ 22¾	17¼ 17⅛	14¼ 14	82 66
CAP, BLASTING: special, nonelectric, M7.	6/pprbd ctn, 1 ctn/wtrprf bag, 50 bag/fbrbd bx, 12 bx (3,600 cap)/wdn bx				
CAP, BLASTING: tetryl, nonelectric, type A.	100/ctn, 50 ctn (5,000 cap)/wdn bx	19	16	8	65
CAP, BLASTING: nonelectric, inert.	As required				

Abbreviations:

bx . . . . . box(es) ctn . . . . . carton lb . . . . . pound pkg . . . .package(s) wdn . . . . wooden
crdbd . . . . cardboard fbrbd . . . . fiberboard mtl . . . . . metal pprbd . . . . paperboard wtrprf . . waterproof

tying them in place or, under some conditions, for holding without tying. It will not adhere satisfactorily to dirty, dusty, wet or oily surfaces; becomes stiff and hard and loses its adhesiveness at subzero temperatures; is softened by water; and becomes useless if wet.

34. Waterproof Sealing Compound

This is used to waterproof the connection between the time blasting fuse and a nonelectric blasting cap and to moistureproof primed dynamite. It does not make a permanent waterproof seal and must not be submerged in water unless the charge is to be fired immediately.

35. Cap Crimper

The M2 cap crimper (fig. 21) is used to squeeze the shell of a nonelectric blasting cap around time fuse, a standard base, or detonating cord securely enough to keep it from being pulled off but not tightly enough to interfere with the burning of the powder train in the fuse or the detonation of the detonating cord. The M2 crimper forms a water resistant groove completely around the blasting cap; however, sealing compound should be applied to the crimped end of the blasting cap for use under water. The rear portion of the jaws is shaped and sharpened for cutting fuse and detonating cord. One leg of the handle is pointed for use in punching fuse wells in explosive materials for the easy insertion of blasting caps. The other leg has a screwdriver end. Cap crimpers being made of a soft nonsparking metal (but they will conduct electricity), must not be used as pliers for any purpose, as this damages the crimping surface. Also the cutting jaws must be kept clean and be used only for cutting fuse and detonating cord.

36. Galvanometer

The galvanometer is an instrument used in testing the electric firing system to check the continuity of the circuit (the blasting cap, firing wire, wire connections, and splices) in

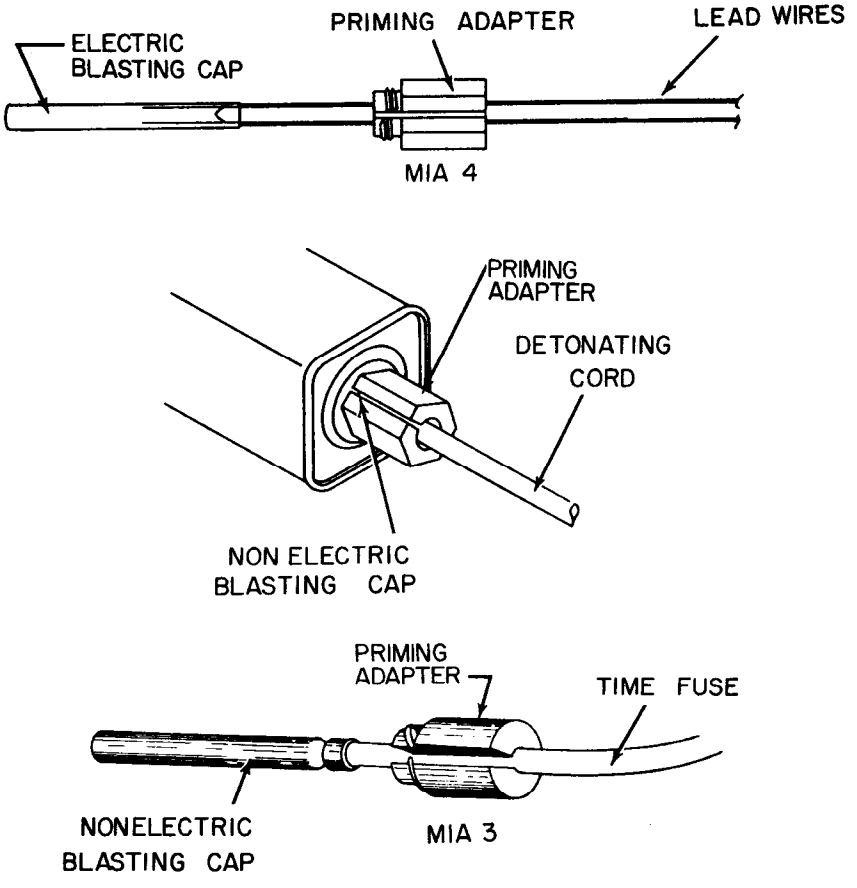


Figure 20. Priming adapters.

order to reduce the possibility of misfires (fig. 22). Its components include an electromagnet, a small special silver-chloride dry cell battery, a scale, and an indicator needle. When the two external terminals are connected in a closed circuit, the flow of current from the dry cell moves the needle across the scale. The extent of the needle deflection depends on the amount of resistance in the closed circuit and on the strength of the battery. The galvanometer must be handled carefully and kept dry. It should be tested before using by holding a piece of metal across its two terminals. If this does not cause a wide deflection of the needle (23 to

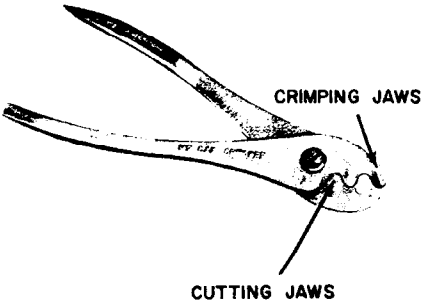


Figure 21. M2 Cap crimper.

25 units) the battery is weak and should be replaced. Being delicate, the instrument must not be opened except to replace a weak cell. When used in a cold climate, the galvanometer should be protected from freezing by keeping it under the clothing near the body, as dry cell batteries tend to cease functioning at temperatures below 0°F.

CAUTION: **Only the special silver-chloride dry cell battery BA 245/U, which produces only 0.9 volts, is to be used in the galvanometer, as other batteries may produce sufficient voltage to detonate electric blasting caps. Because of the tendency to corrode, the battery should be removed from the galvinometer when it is not to be used for extended periods.**

37. Blasting Machine

a. Ten-Cap Blasting Machine. This is a small electric impulse-type generator that produces adequate current (45 volts) to initiate 10 electric caps connected in series if the handle is rotated to the end of its travel. It weighs approximately 5 pounds (fig. 23). The operation is as follows:

(1) Try the machine to see whether or or not it works properly. Operate it several times until it works smoothly before attaching the firing wires.
(2) Fasten the firing wires tightly to the terminals.
(3) Insert the handle.
(4) Insert the left hand through the strap and grasp the bottom of the machine.
(5) Grasp the handle with the right hand and *turn it vigorously clockwise as far as possible.*

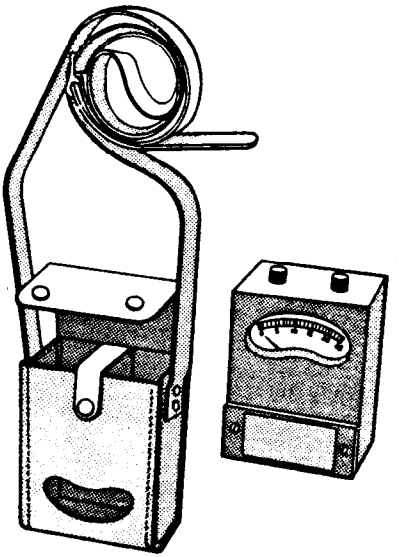


Figure 22. Galvanometer.

b. Thirty-Cap Blasting Machine. This device fires 30 electric caps connected in series. It weighs about 20 pounds. To operate:

(1) Raise the handle to the top of the stroke.
(2) Push the handle down quickly as far as it will go.

c. Fifty-Cap and One-Hundred Cap Blasting Machines.

(1) The 50-cap machine fires 50 electric caps connected in series (fig. 23). It weighs about 20 pounds. Operation is as follows:
   (*a*) Raise the handle to the top of its stroak.
   (*b*) Push the handle down quickly as far as it will go.
(2) The 100-cap machine is similar to the

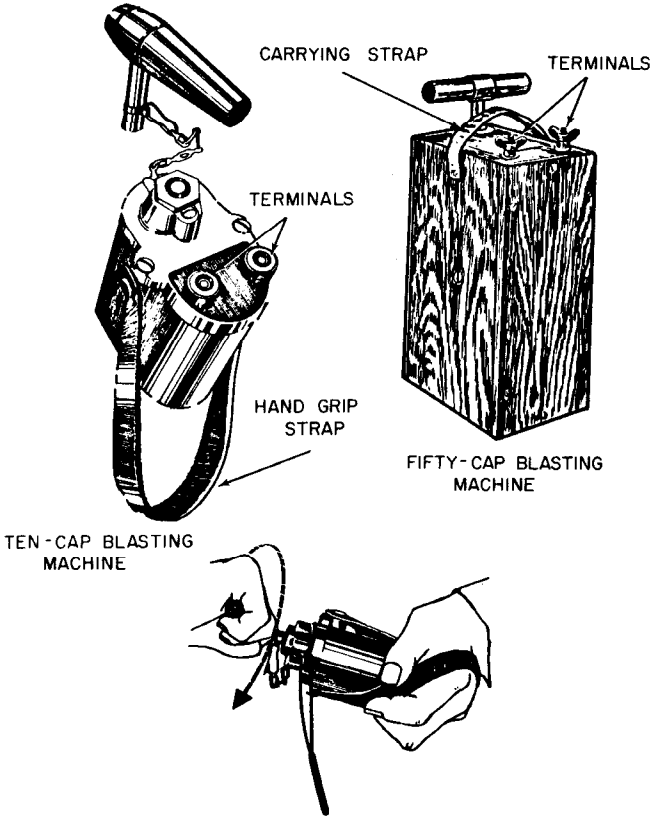


Figure 23. Blasting machines.

50-cap machine except for size and weight and is operated in the same manner. Both are adequate for firing their rated capacity of electric blasting caps connected in series.

38. Firing Wire and Reel

a. Types of Firing Wire. Wire for firing electric charges is issued in 500-foot coils. It is the two-conductor, No. 18 AWG plastic-covered or rubber-covered type. It is carried on the reel unit RL39A, described below. Single-conductor No. 20 AWG annunciator wire in 200-foot coils is issued for making connections between blasting caps and firing wire. WD-1/TT communication wire may also be used. However, it has a resistance of about

40 ohms per 1000 feet, which increases the power requirement (table XXI, app E).

b. Reels.

(1) *RL39A.* This consists of a spool that accommodates 500 feet of wire, a handle assembly, a crank, an axle, and two carrying straps (fig. 24). The fixed end of the wire is extended from the spool through a hole in the side of the drum and fastened to two brass thumbnut terminals. The carrying handles are made of two U-shaped steel rods. A loop at each end encircles a bearing assembly, which is a brass housing with a steel center to accommodate the axle. The crank is riveted to one end of the axle and a cotter pin is placed in the hole at the other to hold the axle in place.

(2) *500-foot reel with detachable handles.* This is a metal drum mounted on an axle to which two detachable D-shaped handles are fastened. The arm with the knob on the side of the drum is used for cranking (fig. 25).

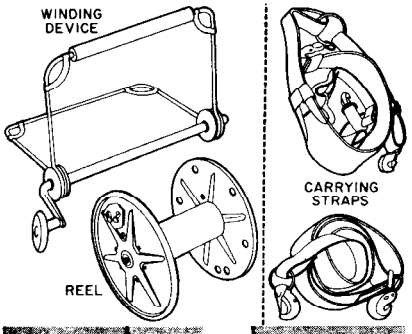


Figure 24. Firing wire reel.

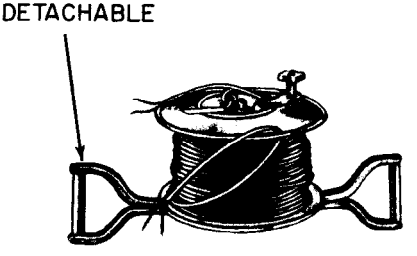


Figure 25. Reel with detachable handles.

(3) *1000-foot reel.* This is similar to (2) above, except that it has a capacity of 1000 feet of firing wire.

39. Detonating Cord Clip

The M1 detonating cord clip (fig. 26) is used to hold together two strands of detonating cord either parallel or at right angles to each other. Connections are made more quickly with these clips than with knots. Also, knots may loosen and fail to function properly if left in place any length of time. Joints made with clips are not affected by long exposure.

a. Branch Line Connections. Branch lines of detonating cord are connected by clipping the branch line with the U-shaped trough of the clip, and the main line with the tongue of the clip, as shown in figure 26.

b. Connecting Two Ends. Ends of detonating cord are spliced by overlapping them about

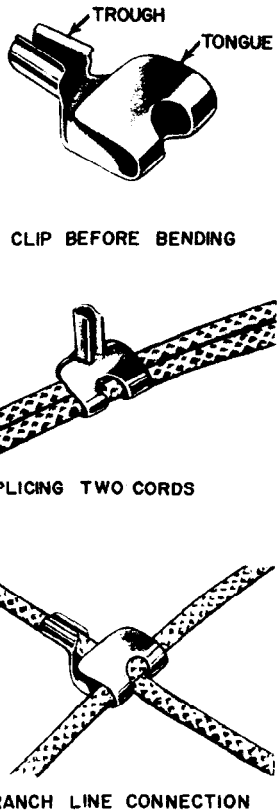


Figure 26. M1 Detonating cord clip.

12 inches, using two clips, one at each end of the overlap, and bending the tongues of the clips firmly over both strands. The connection is made secure by bending the trough end of the clip back over the tongue (fig. 26).

40. Firing Devices and Other Accessory Equipment

a. M10 Universal High Explosive Destructor. The M10 destructor is a high explosive charge in an assembled metal device initiated by means of blasting caps or mine activators with standard firing devices. The destructor has booster cups containing tetryl pellets. The chief function of the destructor is the conversion of loaded projectiles and bombs to improvised demolition charges and the destruction of abandoned ammunition (fig. 27).

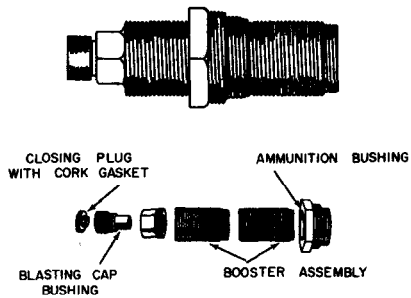


Figure 27. M10 destructor.

b. M19 Explosive Destructor. This device (fig. 28) consists of an explosive-filled cylindrical body with a removable pointed ogive, which may be discarded if not needed. This destructor may be primed with a delay detonator, delay firing device with a special blasting cap, a nonelectric special blasting cap initiated by time blasting fuse or detonating cord, or an electric special blasting cap. The cap well on each end is threaded to receive the standard base coupling or a priming adapter. This device is particularly suitable for use with the dust initiator, described in paragraph 8, appendix E, and similar charges.

c. M1 Concussion Detonator. The M1 concussion detonator is a mechancal firing device actuated by the concussion wave of a nearby blast (fig. 29). It fires several charges simultaneously without connecting them with wire or detonating cord. A single charge fired in any way in water or air will detonate all charges primed with concussion detonators within range of the main charge or of each other (table V). Detonators frequently function at ranges greater than those in table V,

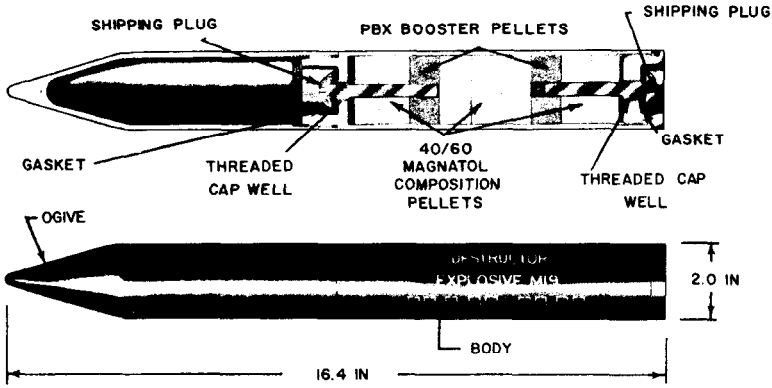


Figure 28. M19 explosive destructor.

but their reliability is then not assured. They should not be used in surf at depths greater than 15 feet, as they function by hydrostatic pressure at a depth of 25 feet. Further, if the salt delay pellet is crumbled due to long storage, the detonator should *not* be used on underwater charges.

Table V. Operating Range of Concussion Detonators

Initiating charge (lb)	In water		In air	
	Depth of water (ft)	Recommended range (ft)	Recommended range (ft)	
			P = 99%	P = 99%
0.5	2	10	—	—
0.5	4	50	—	—
0.5	6	80	—	—
0.5	8	80	—	—
2.5	—	—	12.5	10.8
2.5	2	20	—	—
2.5	4	80	—	—
2.5	6	90	—	—
2.5	8	150	—	—
5	—	—	14.1	11.5
10	—	—	18.8	15.7
15	—	—	21.5	18.0
20	—	—	25.2	21.2
20	2	20	—	—
20	4	80	—	—
20	6	180	—	—
20	8	260	—	—

P=Probability that detonator at indicated distance will be functioned by initiating charge.

d. M1A1 15-Second Delay Friction Detonator.

(1) *Characteristics* (fig. 30). This device consists of a pull friction fuse igniter, 15-second length of fuse, and blasting cap. The blasting cap is protected by a cap screwed on the base.

(2) *Installing.*

(*a*) Unscrew cap protector from base.

(*b*) Secure device in charge.

e. M1A2 (M1E1) 15-Second Delay Percussion Detonator.

(1) *Characteristics* (fig. 31). This item consists of a firing pin assembly joined to a delay housing and primer holding assembly.

(2) *Installing.*

(*a*) Remove cap protector.

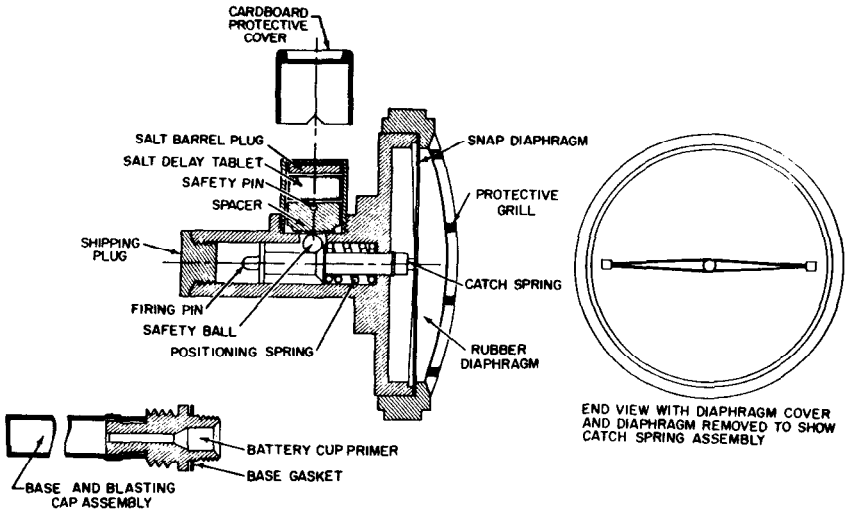
(*b*) Screw device into threaded cap well.

f. M2A1 (M2E1) 8-Second Delay Percussion Detonator.

(1) *Characteristics* (fig. 32). Except for the delay period, marking, and shape of the pull ring, the 8-second delay percussion detonator is identical with *e*, above, in construction, functioning, and installing.

(2) *Installing.*

(*a*) Remove cap protector.



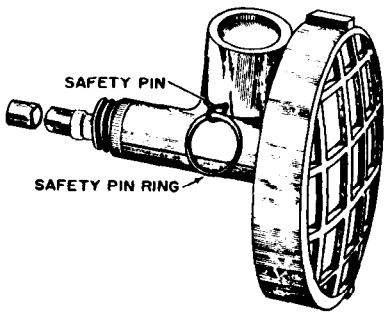


Figure 29. M1 Concussion detonator.

(*b*) Screw device into threaded cap well.

g. M2 8-Second Delay Friction Detonator.

(1) *Characteristics* (fig. 33). This device consists of a friction-type fuse lighter, an 8-second length of fuse, and a blasting cap. The blasting cap is protected by a cap screwed on the base.

(2) *Installing.*

(*a*) Unscrew cap protector from base.

(*b*) Secure device in charge.

h. M1 Delay Firing Device.

(1) *Characteristics* (fig. 34).

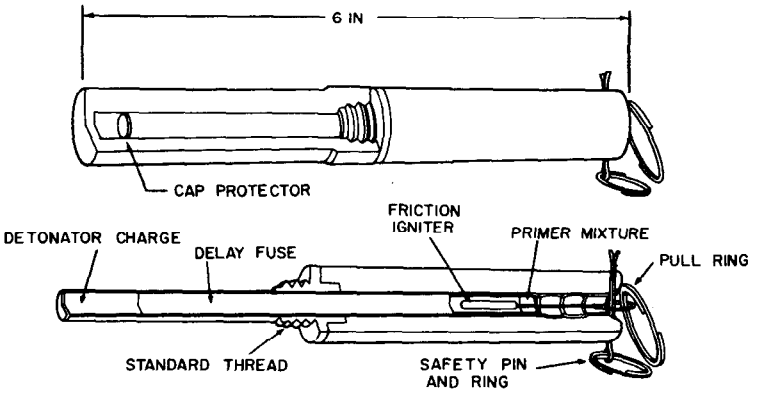


Figure 30. M1A1 15-second delay friction detonator.

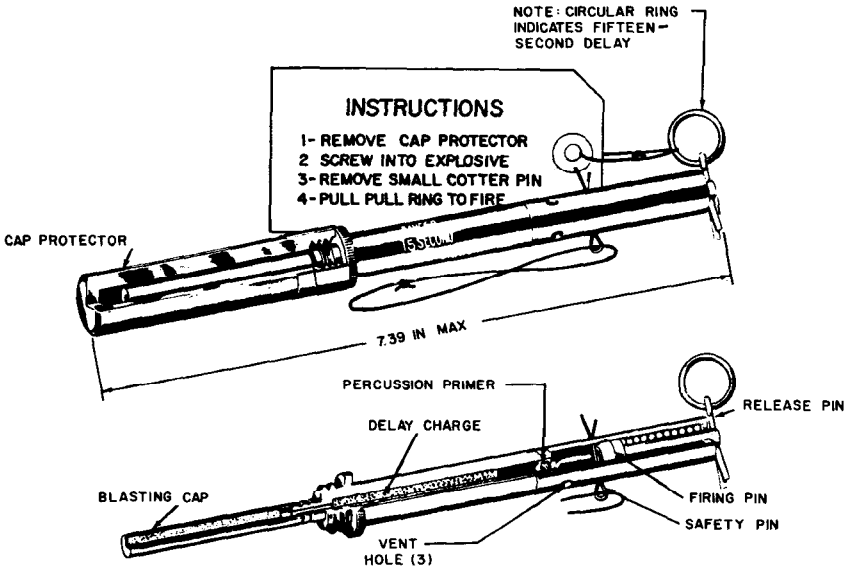


Figure 31. M1A2 (M1E1) 15-second delay percussion detonator.

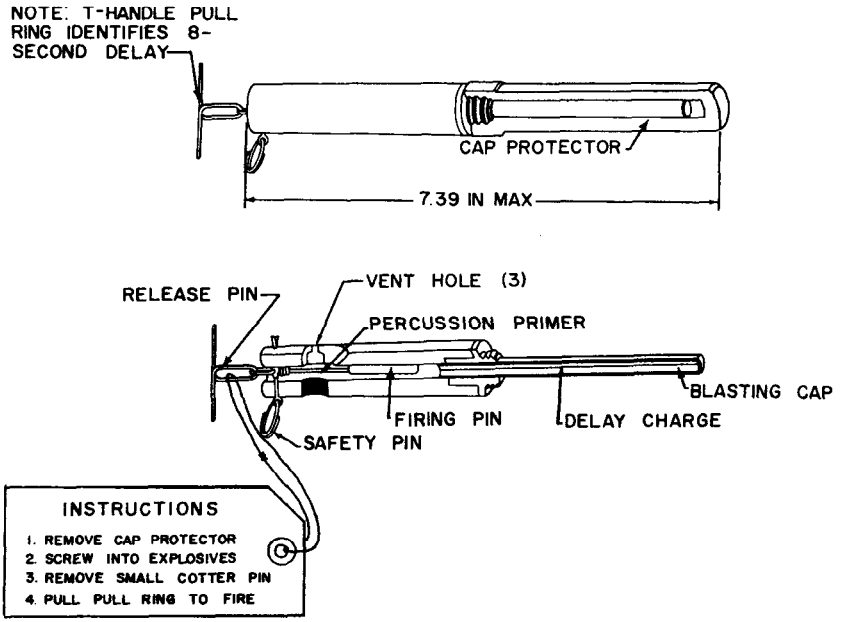


Figure 32. M2A1 (M2E1) 8-second delay percussion detonator.

Case	Color	Dimensions		Internal action	Delay
		D	L		
Copper and brass	Natural metal	7/16 in	6¼ in	Mechanical with corrosive chemical release.	1 min to 23 days, identified by color of safety strip.

Safety	Packaging
Colored metal strip inserted in slot above percussion cap.	10 units—2 red, 3 white, 3 green, 1 yellow, and 1 blue—and a time delay table packed in paperboard carton, 10 cartons in fiberboard box, and 5 boxes in wooden box.

(2) *Installing.*

(*a*) *Select device of proper delay* (table VI).

(*b*) Insert nail in inspection hole to make sure that firing pin has not been released. If the firing pin has been released, the nail cannot be pushed through the device.

Table VI. Temperature Corrections for M1 Delay Firing Device

Temp (deg F)	Black		Red		White		Green		Yellow		Blue		Temp (deg C)
	OM	ST	OM	ST	OM	ST	OM	ST	OM	ST	OM	ST	
-25			8.5 hr	3.3 hr	3 da	1.3 da							-32
0	8 hr	2.5 hr	45 min	20 min	17.5 hr	8 hr	2.6 da	1.2 da	8.5 da	3.8 da	23 da	10 da	-18
+25	36 min	16 min	25 min	11 min	5.5 hr	2.5 hr	17 hr	8 hr	2.0 hr	20 hr	5.0 da	2.2 da	-4
50	15 min	7 min	17 min	8 min	2 hr	55 min	6 hr	2.7 hr	14 hr	6.0 hr	1.3 da	14 hr	+10
75	9 min	4 min	15 min	7 min	1 hr	27 min	2.5 hr	70 min	5.5 hr	2.5 hr	11.5 hr	5 hr	24
100	5 min	2.0 min	8 min	3.5 min	32 min	14 min	70 min	30 min	2.5 hr	65 min	5.2 hr	2.3 hr	38
125	4 min	1.5 min	5 min	2 min	20 min	9 min	35 min	15 min	80 min	36 min	2.5 hr	1.1 hr	52
150	3 min	1 min	4 min	1.5 min	15 min	6 min	20 min	9 min	46 min	21 min	80 min	36 min	66

OM—Most likely delay if two devices are used in the same charge. If only a single device is used, this value should be increased approximately 15 percent.

ST—Reasonable safe time. Delays of less than this value should not occur more than one in a thousand.

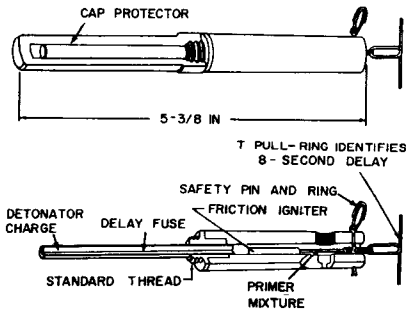


Figure 33. M2 8-second delay friction detonator.

(*c*) Remove protective cap from base.

(*d*) With crimper attach nonelectric blasting cap to base. *Crimper jaws should be placed no further than ¼ inch from open end of blasting cap.*

(*e*) Secure firing device in charge.

(*f*) Crush glass ampoule between thumb and fingers.

(*g*) Remove safety strip.

Caution: **If safety strip does not remove easily, remove and discard device.**

i. M1A1 Pressure Firing Device.

(1) *Characteristics* (fig. 35).

Case	Color	Dimensions		Internal action	Operating pressure
		D	L		
Metal	OD	⅝ in	2 ⅝ in	Spring-driven striker with trigger pin and keyhole slot release.	20 lb or more.

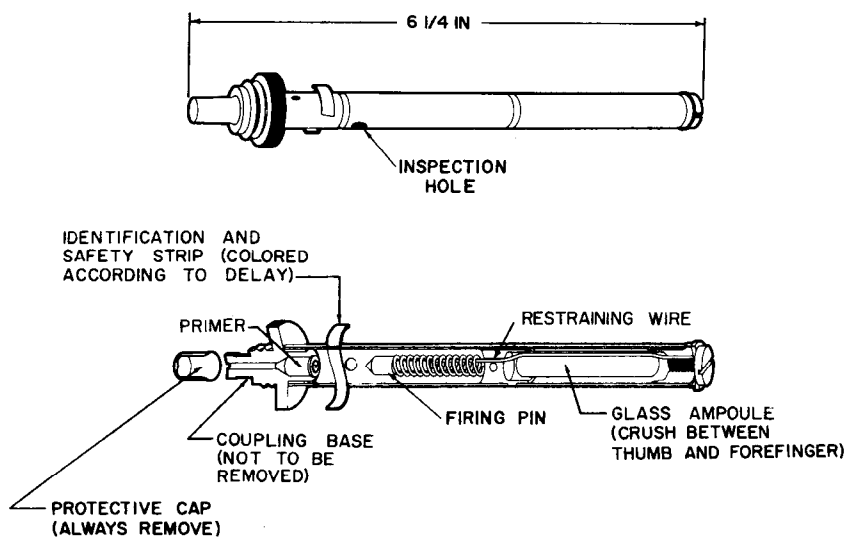


Figure 34. M1 delay firing device.

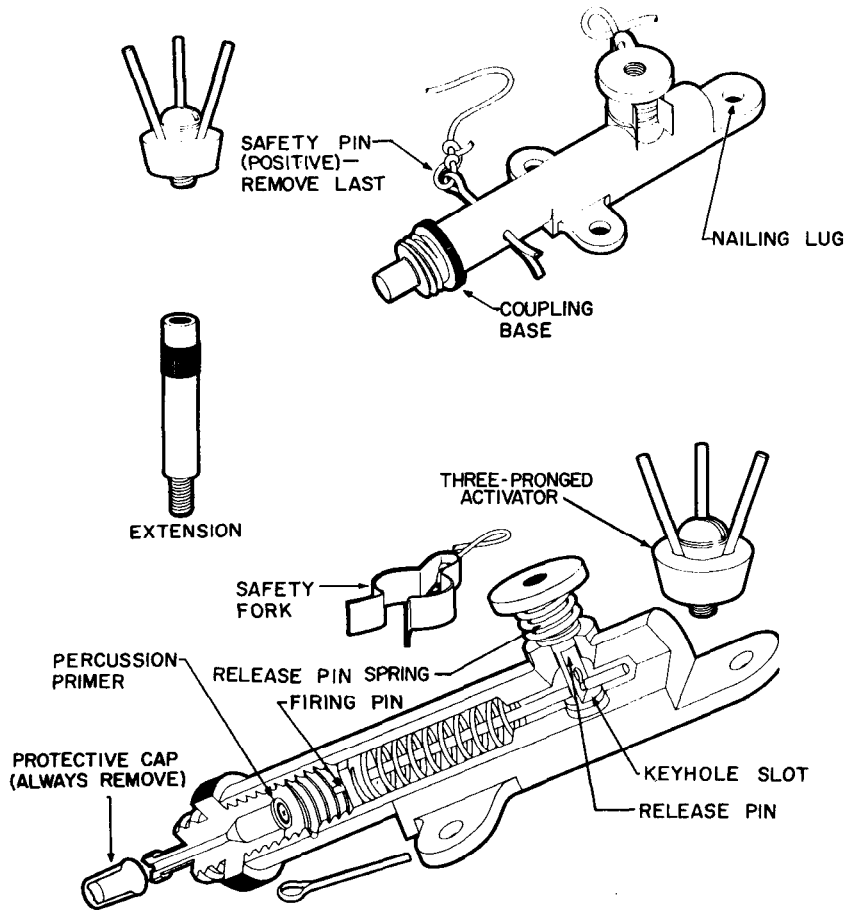


Figure 35. M1A1 pressure firing device.

Safeties	Accessories	Packaging
Safety fork and positive safety pin.	3-pronged pressure head and extension rod.	Five units, with percussion caps packed in cardboard carton. Fifty cartons shipped in wooden box.

(2) *Installing.*

(*a*) Remove protective cap from base and crimp on a nonelectric blasting cap. *Crimper jaws should be placed no farther than ¼ inch from open end of blasting cap.*

(*b*) Assemble 3-pronged pressure head and extension rod and screw in top of pressure cap, if needed.

(*c*) Attach firing device assembly to charge.

(*d*) Remove safety fork first, and positive safety last.

j. M1. Pull Firing Device.

(1) *Characteristics* (fig. 36).

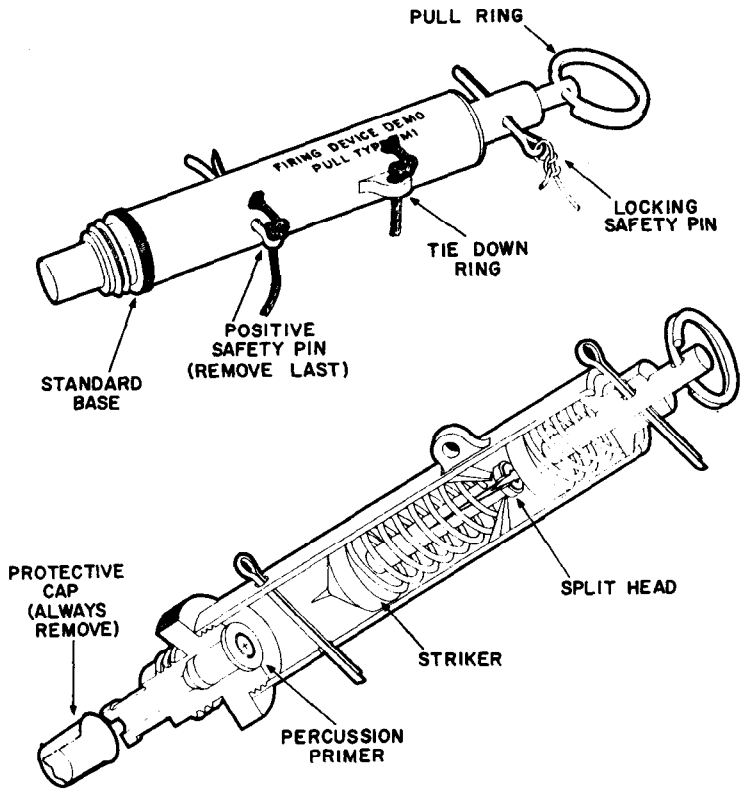


Figure 36. M1 pull firing device.

Case	Color	Dimensions		Internal action	Operating force
		D	L		
Metal	OD	9/16 in	3 5/16 in	Mechanical with split-head striker release.	3 to 5 lb pull on trip wire.

Safeties	Packaging
Locking and positive safety pins.	Five units complete with percussion caps and two 80-ft spools of trip wire are packed in chipboard container. Forty chipboard containers are packed in wooden box.

2. *Installing.*
   (*a*) Remove protective cap.
   (*b*) With crimpers, attach nonelectric blasting cap to standard base. *Crimper jaws should be placed no farther than 1/4 inch from open end of blasting cap.*
   (*c*) Attach firing device assembly to charge.
   (*d*) Attach anchored pull wire.
   (*e*) Remove *locking safety pin first,* and *positive safety pin last.*

k. M3 Pull-Release Firing Device.
   (1) *Characteristics* (fig. 37).

Case	Color	Dimensions		Internal action	Operating pressure
		D	L		
Metal	OD	9/16 in	4 in	Mechanical with spreading striker head release.	Direct pull of 6 to 10 lb.

Safeties	Packaging
Locking and positive safety pins.	Five units with two 80-ft spools of trip wire in carton, and 5 cartons packed in wooden box.

   (2) *Installing.*
   (*a*) Remove protective cap.
   (*b*) With crimpers, attach blasting cap to standard base. *Crimper jaws should be placed no farther than 1/4 inch from open end of blasting cap.*
   (*c*) Attach firing device to anchored charge (must be firm enough to withstand pull of at least 20 pounds).
   (*d*) Secure one end of trip wire to anchor and place other end in hole in winch.
   (*e*) With knurled knob, draw up trip wire until locking safety pin is pulled into wide portion of safety pin hole.
   (*f*) Remove *locking safety pin first* and *positive safety pin last.*

l. M5 Pressure-Release Firing Device.
   (1) *Characteristics* (fig. 38).

Case	Color	Dimensions			Internal action	Initiating action
		L	W	Ht		
Metal	OD	1 3/4 in	15/16 in	11/16 in	Mechanical with hinged plate release.	Removal of restraining weight—5 lb or more.

Safeties	Packaging
Locking safety pin and hole for improvised positive safety pin.	Four firing devices complete and four plywood pressure boards in paper carton. Five cartons are packaged in fiber board box and ten of these in wooden box.

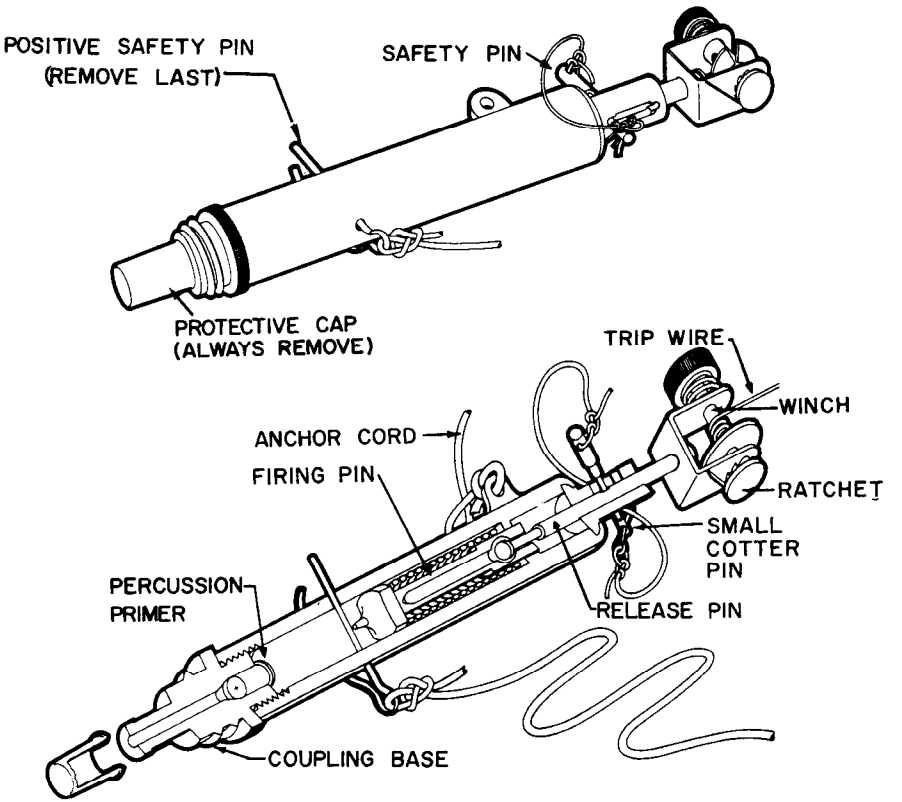


Figure 37. M3 pull-release firing device.

(2) *Installing.*

(*a*) Insert a length of 10-gage wire in interceptor hole.

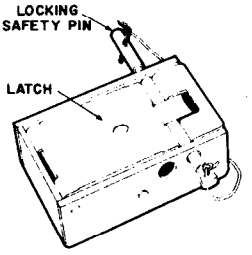
(*b*) Bend slightly to prevent dropping out.

(*c*) Remove small cotter pin from safety pin.

(*d*) Holding release plate down, replace locking safety pin with length of 16 or 18 gage wire. Bend wire slightly to prevent dropping out.

(*e*) Remove protective cap from base and with crimpers, attach blasting cap. *Crimper jaws should be placed no farther than ¼ inch from open end of blasting cap.*

(*f*) Secure firing device assembly in charge.



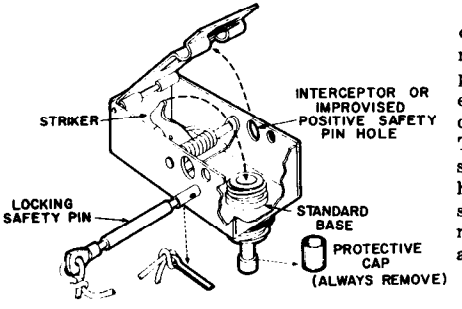


Figure 38. M5 pressure-release firing device.

(*g*) Emplace charge and set the restraining weight (5 pounds or more) on top of the firing device.

(*h*) Slowly and carefully, without disturbing the restraining weight, remove the improvised locking safety pin first and the improvised positive safety pin from the interceptor hole last. The pins should remove easily if the restraining weight is adequate and positioned properly.

m. M2 Weatherproof Lighter. This device was designed as a positive method of lighting time blasting fuse (fig. 39). It operates effectively under all weather conditions—even under water if it is properly waterproofed. A pull on the striker retaining pin causes the striker to hit the primer, igniting the fuse. A sealing compound is applied between the fuse and the lighter to retard any flash that may come from lighting the fuse.

n. M60 Weatherproof Fuse Lighter. This device is designed to ignite blasting fuse in all sorts of weather conditions and under water if waterproofed. The fuse is inserted into a fuse retainer and sealed and weatherproofed by means of two rubber washer seals (fig. 40). A pull on the pull ring releases the striker assembly, allowing the firing pin to drive against the primer, which ignites and initiates the fuse. For further information, see paragraph 43*i*.

o. Computing Tape. The demolition charge computing tape (fig. 41), provides a rapid method of calculating the weight of TNT (in pounds) needed to carry on a demolition project. It combines in an abbreviated form most of the formulas and tables provided in this text. The assembly consists of two 6-foot flexible steel spring retractable tapes in joined metal housings. The two tapes have a total of five sets of markings. A rigid embossed scale is mounted on one side of the housing. The scales are—

(1) *First tape (breaching and pressure scales).* The upper side of this tape indicates the pounds of TNT required to breach concrete, masonry, timber, or earthen walls, making allowances for the tamping and placement of charges. The weight is read directly to the right of the mark that indicates the thickness of the wall or obstacle. The lower side of the tape has information on breaching concrete beams, roadways, and bridge spans. It is used to measure the thickness of the target or element. The weight of the charge may be read directly from the tape without consideration of the actual dimensions of the target.

(2) *Second tape (steel- and timber-cutting scales).* This tape contains the requirements for cutting steel and timber construction materials. One side shows the weight of TNT needed for

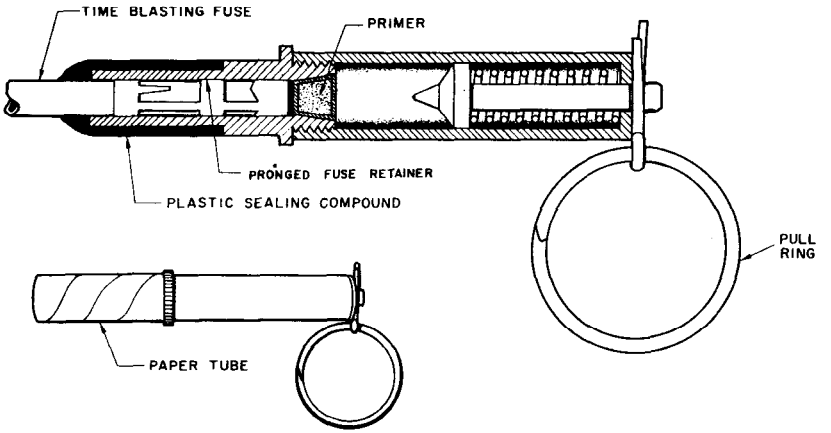


Figure 39. M2 weatherproof fuse lighter.

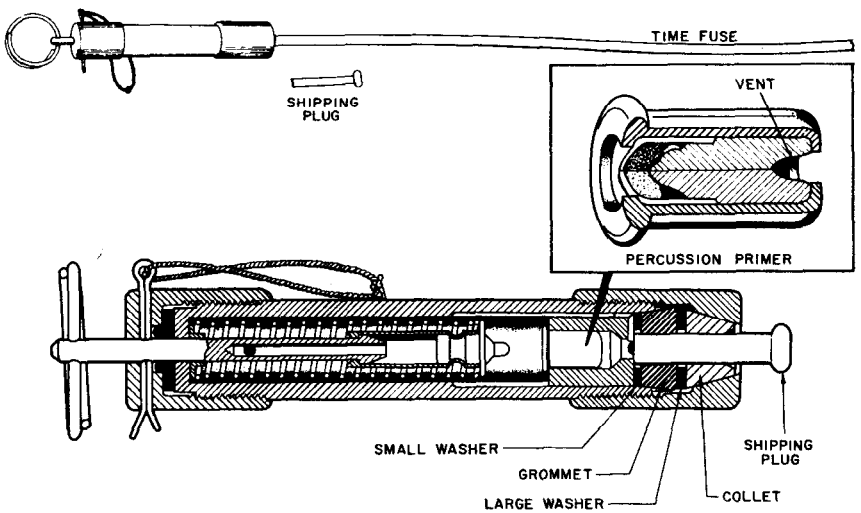


Figure 40. M60 weatherproof fuse lighter.

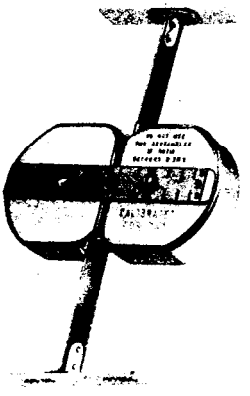


Figure 41. Computing tape.

cutting timber for both internal and external placement. The reverse side has a rule for the calculation of the cross-sectional area of steel members and also the formulas for cutting steel.

(3) *Bar and rod-cutting scale.* The small scale on the exterior of the case is used for making calculations for the cutting of rods, bars, chains, and cables. The number of pounds of TNT needed for cutting is read directly from the scale.

p. Demolition Card. This pocket sized card (GTA 5–10–9, May 65) gives data in tabulated form for the calculation of pressure, timber-cutting, steel-cutting, breaching, and cratering charges.

q. Rivet-Punching Powder-Actuated Driver (Ram-Set Gun).

(1) *Description.* This is a riveting machine powered by the gases generated by a fired cartridge (fig. 42). It is hand-operated, air-cooled, and feeds from a magazine with a 10-cartridge fastener unit capacity. It operates effectively under water. The waterproofed fastener unit has a sharp point and a coarsely knurled body to provide maximum holding power in light steel, softer metals, concrete, and heavy wood. The sabot, an annular threaded unit, screws on the rear of the fastener to guide it in ejection, acts as a stop-shoulder, and provides additional bearing on the penetrated material. The cartridge case is a specially wadded caliber .38 steel case. A manual device is provided for cocking the driver under water.

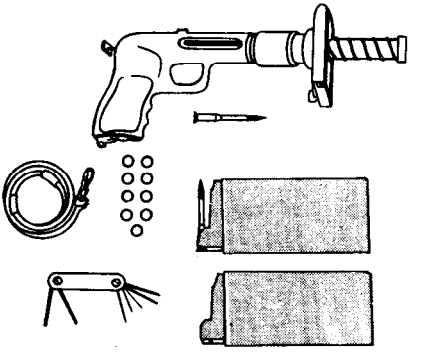


Figure 42. Ram-set gun.

(2) *Operation.* The firing of the cartridge propels the fastener and sabot into the target. The fastener acts as a rivet for attaching charges to steel, concrete, or wooden targets. The device is especially useful where working space is severely limited and for underwater work. *Do not fire the gun into explosive or immediately adjacent to exposed explosives.*

r. Earth Augers and Diggers. Two types of earth augers, hand-operated and motorized, are used for boring holes for the placement of cratering charges and bridge-abutment demolition charges. Motorized earth augers will bore holes to a depth of approximately 9 feet. Boring speed depends on the type and consist-

ency of the soil, being most rapid in light earth or loam. Earth augers and diggers cannot be used satisfactorily in soil containing large rocks.

(1) *Hand-operated posthole auger.* The 10-inch posthole auger (fig. 43) is capable of boring a hole large enough for the 40-pound ammonium nitrate cratering charge and other charges of equal size. The extension handle permits boring as deep as 8 feet.

(2) *Posthole digger.* This tool (fig. 43) has two concave metal blades on hinged wooden handles. The blades are forced into the earth and the soil is removed by lifting and pulling the handles apart.

(3) *Motorized earth auger.* Motorized earth augers drill hole 8, 12, 16, or 20 inches in diameter to depths up to 8 feet.

s. Pneumatic Tools. These are the rock drill, pavement breaker, and wood-boring machine. The *rock drill* bores holes up to 2 inches in diameter in rock, concrete, or masonry for the placement of internal charges. The *pavement breaker* is used to shatter the hard surface of roads before drilling boreholes with an auger for cratering charges. The *wood-boring machine* drills boreholes in wood for the placement of internal charges.

41. Blasting Kits

These kits or sets are assemblies of demolition explosive items, accessories, and tools needed for various jobs. They are issued according to tables of equipment.

a. Electric and Nonelectric Kit. The electric and nonelectric demolition equipment set consists of TNT and M5A1 (Composition C-4) demolition blocks and accessories for electric and nonelectric priming and firing (fig. 44). The set is carried in the engineer squad and platoon demolition chest.

(1) *Components issued as basic kit.* The basic kit consists of items listed below. These may be requisitioned separately for replacement purposes.

Quantity	Item
2	Bag, canvas, carrying, demolition kit
1	Blasting machine, ten-cap capacity
5	Box, cap, ten-cap capacity, infantry
1	Chest, demolition, engineer platoon, M1931
2	Crimper, cap, M2 (w/fuse cutter)
1	Galvanometer, blasting, (w/leather case and carrying strap)
2	Knife, pocket
2	Pliers, lineman's (w/side cutter), length 8 in

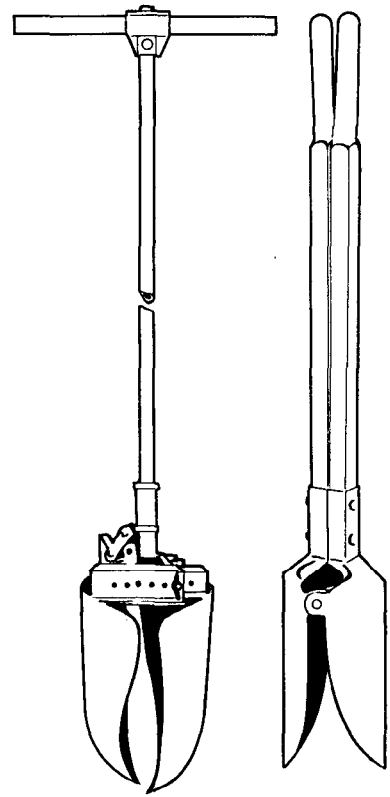


Figure 43. Hand-operated digging tools.

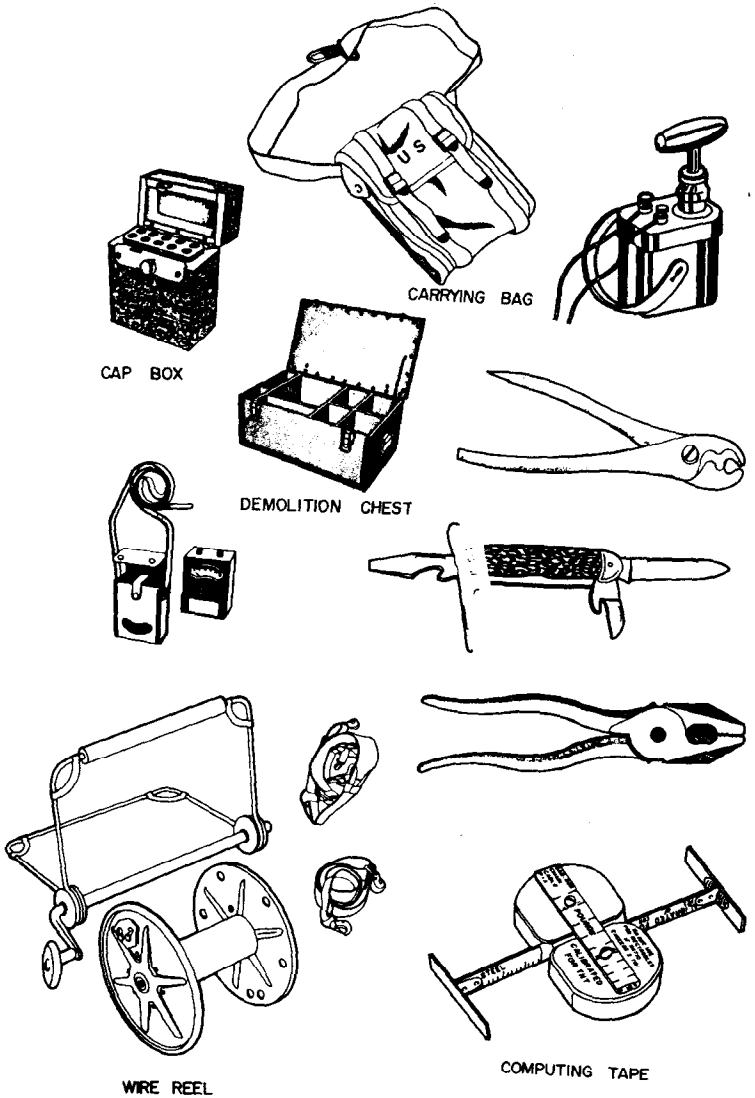


Figure 44. Electric and nonelectric blasting kit.

Quantity	Item
1	Reel, wire, firing, 500 ft, RL-39A, (w/ carrying straps, w/winding device, w/ spool, w/o wire)
2	Tape, computing, demolition charge

(2) *Components issued separately.* The following items are required to complete the kit and should be on hand at all times. These items are not supplied with the kit, and must be requisitioned separately.

(*a*) *Nonexplosive components.*

Quantity	Item
60	Adapter, priming, M1A4
2	Adhesive, paste, for demolition charges, ½-lb can, M1
1	Cable, power, electrical, firing, vinyl polymer insulation, two conductor, No. 18 AWG stranded, 500-ft coil
50	Clip, cord, M1, detonating
6	Insulation tape, electrical, black adhesive, ¾-in wide
1	Sealing compound, blasting cap, waterproof, ½-pt can
2	Twine, hemp, No. 18,8-oz. ball
2	Wire, electrical, annunciator, waxed double cotton wrapped insulation, solid single conductor, No. 20 AWG, 200-ft coil

(*b*) *Explosive components.*

Quantity	Item
50	Cap, blasting, special, electric M6
50	Cap, blasting, special, nonelectric M7
40	Charge, demolition, block, M5A1 2½-lb Comp C–4
50	Charge, demolition, block, 1-lb (TNT)
5	Cord, detonating, fuze, primacord, 100-ft spool
5	Destructor, explosive, universal M10
2	Fuze, blasting, time, 50-ft coils
50	Igniter, blasting fuze M60, weatherproof

b. Nonelectric Kit.

(1) *Components issued as basic kit.* The basic kit (fig. 45) consists of the items listed below. These items may also be requisitioned separately for replacement purposes.

Quantity	Item
2	Bag, canvas, carrying, demolition kit
2	Box, cap, 10-cap capacity, infantry
2	Crimper, cap, M2 (w/fuse cutter)
2	Knife, pocket
2	Tape, computing, demolition charge

(2) *Components issued separately.* The following items are required to complete the kit and should be on hand at all times. They must be requisitioned separately, however.

(*a*) *Nonexplosive components.*

Quantity	Item
20	Adapter, priming, M1A4
2	Adhesive, paste, for demolition charges, ½ lb can M1
50	Clip, cord, M1, detonating
2	Insulation tape, electrical, black adhesive, ¾ in wide
1	Sealing compound, blasting cap, waterproof, ½ pt can

(*b*) *Explosive components.*

Quantity	Item
50	Cap, blasting, special, nonelectric, M7
40	Charge, demolition, block, M5A1, 2½ lb, Comp C–4
2	Cord, detonating, fuze, primacord, 100 ft spool
2	Destructor, explosive, universal, M10
2	Fuze, blasting, time, 50-ft coils
50	Igniter, blasting fuze, M60, weatherproof

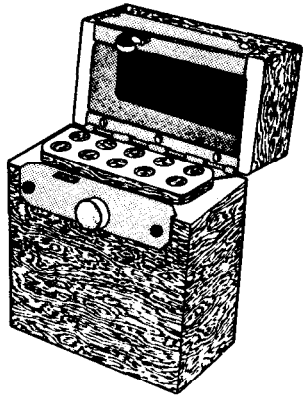
c. Earth Rod Kit.

(1) *Use.* This kit (fig. 46), is used for making holes for demolition or constructional purposes as deep as 6 feet and as large as several inches in diameter in earth and soft shale. It is not usable in rock or other hard material. The rod is driven into the earth by the propelling charge, which is exploded in the firing chamber. A removable handle (extractor rod), which fits through the holes in the firing chamber, and an extension are used for gripping and lifting the rod or pulling it from the earth. A linear charge is furnished for enlarging the diameter of the hole. A forked inserting rod also is furnished for inserting improvised linear charges when the standard ones are not available.

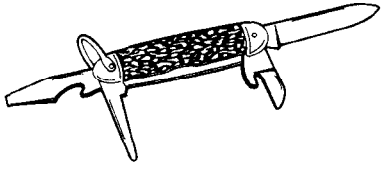
(2) *Components.*

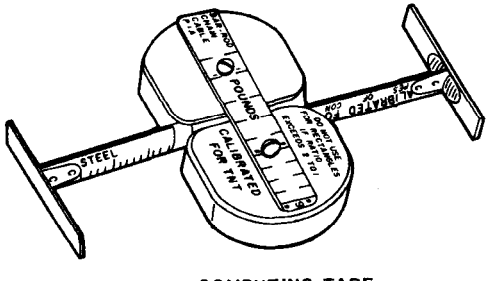
Note. The item letters in (*a*) and (*b*) below are keyed to figure 46.

CARRYING BAG



CAP BOX





COMPUTING TAPE

Figure 45. Nonelectric blasting kit.

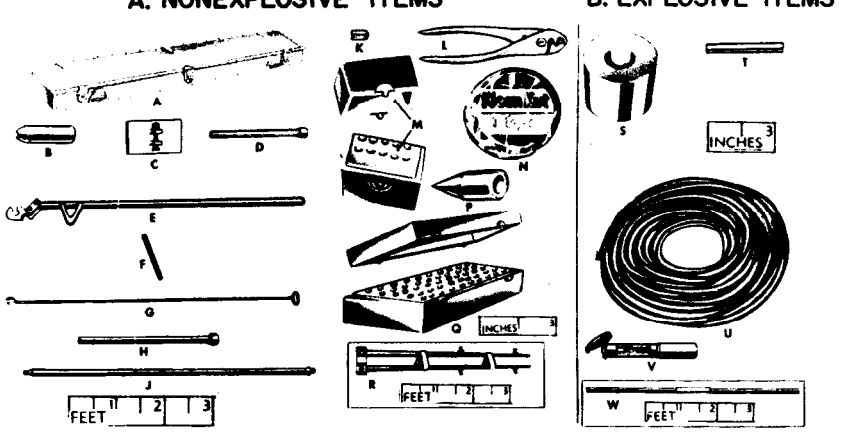


Figure 46. Earth rod kit.

(*a*) *Nonexplosive items.*

Item letter	*Quantity*	*Item*
A	1	Chest
B	1	Chamber, firing
C	1	Plate, base, extractor, assy
D	1	Rod, extension
E	1	Extractor, rod
F	1	Rod, handle and starting
G	1	Rod, inserting
H	2	Rod, intermediate
J	2	Rod, main, long
K	100	Adapter, priming, explosive, M1A3 or M1A4
L	1	Crimper, cap, M2 (w/fuse cutter)
M	1	Box, cap, 10-cap capacity, infantry
N	2	Insulation tape, electrical, black adhesive cotton, ¾-inch wide
P	100	Point
Q	2	Box, cap, 50-cap capacity, engineer
R	1	Tripod

(*b*) *Explosive items.*

Item letter	*Quantity*	*Item*
S	100	Charge, propelling, earth rod, M12 (w/primer, M44)
T	100	Cap, blasting, special, non-electric (type I (J-1 PETN))
U	2	Fuze, blasting, time 50-ft coils
V	200	Igniter, time blasting fuze, M2, weatherproof
W	100	Charge, demolition, linear (two 3-ft sections and one connecting sleeve)

CHAPTER 2

FIRING SYSTEMS

Section I. NONELECTRIC FIRING SYSTEM

42. Introduction

Two types of systems for firing explosives are in general use—electric and nonelectric. Both have their individual priming methods and materials. In addition, detonating cord may be used with both systems to improve and make them more efficient and effective, as described in paragraphs 63 through 71.

43. System Components and Assembly for Detonation

A nonelectric system is an explosive charge prepared for detonation by means of a nonelectric blasting cap. The priming materials consist of a nonelectric blasting cap, which provides the shock adequate to initiate the explosive, and the time fuse, which transmits the flame that fires the blasting cap. The assembly of the nonelectric system follows.

a. Cut and discard a 6-inch length from the free end of the time fuse (A, fig. 47). Do this to be sure that there is no chance of misfire from a damp powder train because of the absorption of moisture from the open air. Then cut off a minimum of 3 feet of time fuse to check the burning rate. A more exact check may be made by marking off 1-foot lengths, timing them separately, and taking the average.

b. Cut the time fuse long enough to permit the person detonating the charge to reach a safe distance by walking at a normal pace before the explosion. This cut should be made squarely across the time fuse.

c. Take one blasting cap from the cap box, inspect it, hold it with the open end down, and shake it gently or bump the hand holding it against the other hand, to remove any dirt or foreign matter. *Never tap the cap with a hard object or against a hard object. Never blow into the cap. Do not insert anything into the cap to remove any dirt or foreign material.*

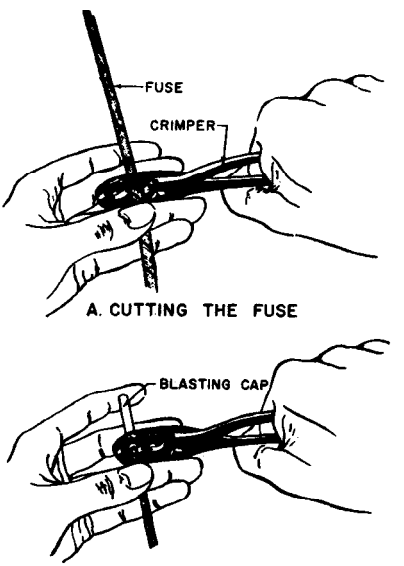


Figure 47. Capping the fuse.

d. Hold the time fuse vertically with the square cut end up and *slip the blasting cap gently down over it so that the flash charge in the cap is in contact with the end of the time fuse; if not, it may misfire. Never force the time fuse into the blasting cap by twisting or*

any other method. If the end is flattened or it is too large to enter the blasting cap freely, roll it between the thumb and fingers until the size is reduced to permit free entry.

e. After the blasting cap has been seated, grasp the time fuse between the thumb and third finger of the left hand and extend the forefinger over the end of the cap to hold it firmly against the end of the time fuse. Keep a slight pressure on the closed end of the cap with the forefinger (B, fig. 47).

f. Slide the second finger down the outer edge of the blasting cap to guide the crimpers (B, fig. 47) and thus obtain accurate crimping, even in darkness.

g. Crimp the blasting cap at a point ⅛ to ¼ of an inch from the open end. *A crimp too near the explosive in the blasting cap may cause detonation. Point the cap out and away from the body during crimping.* Double-crimp the cap, if necessary, for weatherproofing.

Note. If the blasting cap should remain in place several days before firing, protect the joint between the cap and the time fuse with a coating of sealing compound or some similar substance. *(As this sealing compound, a standard issue, does not make a waterproof seal, submerged charges should be fired immediately).*

h. Pass the end of the time fuse through the priming adapter. (The time fuse should move through the adapter easily.) Then pull the cap into the adapter until it stops, insert into the cap well of the explosive, and screw the adapter into place. If no priming adapter is available, insert the capped time fuse into the cap well and tie it in place with a string or fasten it with adhesive tape or some other available material. (For details of nonelectric priming of demolition blocks, see para 44–46.)

i. Attach M60 weatherproof fuse lighter as follows:

(1) Unscrew the fuse holder cap two or three turns but do not remove. Press the shipping plug into the lighter to release the split collet (fig. 40), and rotate the plug as it is removed.

(2) Insert the free end of the time fuse in place of the plug until it rests against the primer.

(3) Tighten the cap sufficiently to hold the fuse in place and thus weatherproof the joint.

(4) To fire, remove the safety pin, hold the barrel in one hand, and pull on the pull ring with the other, taking up the slack before making the final strong pull. In the event of a misfire, the M60 can be reset quickly without disassembly by pushing the plunger all the way in and attempting to fire as before. (It cannot be reset underwater, however, because water can enter the interior of the nylon case through the holes in the pull rod. The fuse lighter is reusable if the primer is replaced.)

j. Light the time fuse with a match by splitting the fuse at the end (fig. 48), placing the head of an unlighted match in the powder train, and then lighting the inserted match head with a flaming match or by rubbing the abrasive on the match box against it.

Note. The M2 weatherproof fuse lighter (fig. 39) may be attached by sliding the fuse retainer over the end of the fuse, firmly seating it, and applying sealing compound at the joint between the time fuse and the lighter to retard any flash that may come from lighting the time fuse. In firing, hold the barrel in one hand and pull on the pull ring with the other.

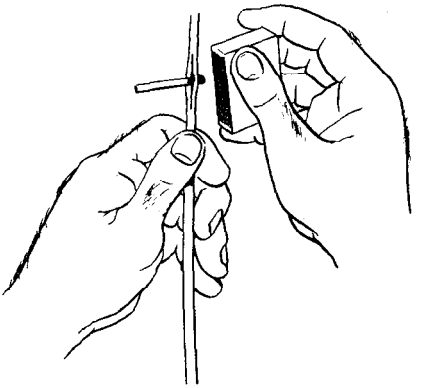


Figure 48. Lighting time fuse with match.

44. Nonelectric Priming of Demolition Blocks

a. With Priming Adapter. Priming adapters simplify the priming of military explosives with threaded cap wells. The shoulder inside one end of the adapter is large enough to admit time fuse or detonating cord, but too small for a blasting cap. The other end of the adapter fits the internal thread of threaded cap wells in military explosives. The nonelectric priming components are assembled as shown in figure 49.

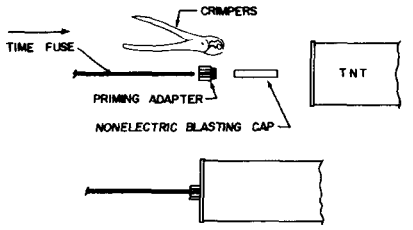


Figure 49. Nonelectric priming, using priming adapter.

b. Without Priming Adapter. When a priming adapter is not available but explosive blocks have threaded cap wells, they are primed as follows (see method 1, fig. 50):

(1) Wrap a string tightly around the block and tie it securely leaving about 6 inches of loose string on each end after making the tie (method 1, fig. 50).

(2) Insert a blasting cap with fuse attached into the cap well.

(3) Tie the loose string around the fuse to prevent the blasting cap from being separated from the block.

c. Without Cap Well.

(1) If the demolition block has no cap well, make a hole in the end large enough to receive the cap with a pointed instrument or the pointed leg of the crimper handle (method 2, fig. 50).

(2) Insert fused cap into hole, grasp fuse with thumb and forefinger at top of hole, and remove fused cap from the block of explosive.

(3) Using string approximately 40 inches in length, tie two half hitches around fuse so the tie will be at the top of the hole when reinserted.

(4) Insert fused cap into hole and wrap long end of string around the block of explosive a minimum of three times along the long axis, each time changing the direction of tie with a half turn around the time fuse, keeping the string taut.

(5) Tie off around the time fuse at top of hole with two half hitches.

Note. Never try to force a cap into an expedient fuse well that is too small to admit it easily.

45. Nonelectric Priming of M1 Chain Demolition Block

The M1 chain, demolition block is primed nonelectrically by fastening a nonelectric blasting cap at a point at least 6 inches in from one of the free ends of the detonating chord chain as shown in figure 51. *The explosive end of the cap should point toward the demolition blocks.* The firing of the blasting cap detonates the cord, which in turn detonates the explosive blocks.

46. Nonelectric Priming of Plastic Explosive (C3 and C4)

a. The M5 (C3) and M5A1 (C4) demolition blocks with threaded cap wells or recesses and with or without priming adapters and the M3 (C3) demolition block without a threaded cap well are primed nonelectrically as described in paragraph 44 and shown in figures 49 and 50.

b. Plastic explosive removed from the container is primed nonelectrically by molding it around a fused blasting cap (fig. 52). The explosive must be at least one inch thick at the explosive end of the blasting cap and ½ inch thick at the sides to insure detonation.

47. Nonelectric Priming of Dynamite

Dynamite cartridges may be primed nonelectrically at either end or at the side. End prim-

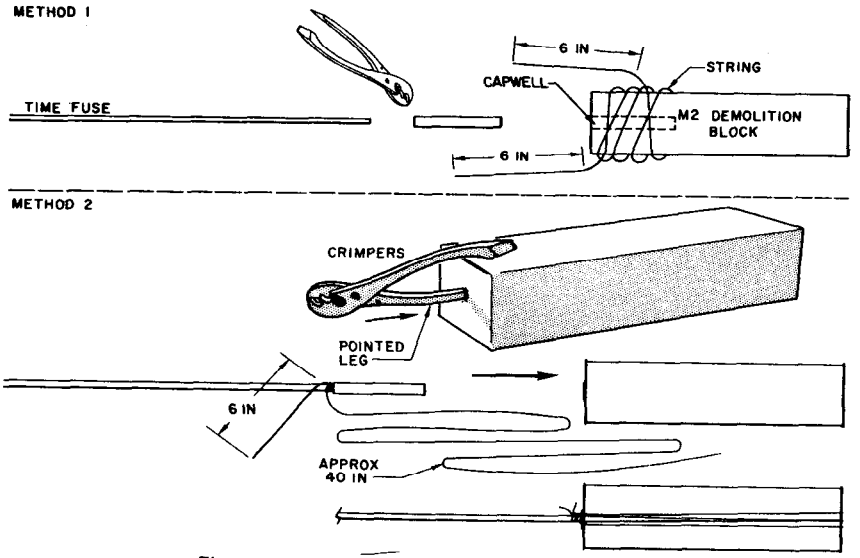


Figure 50. Nonelectric priming without priming adapter.

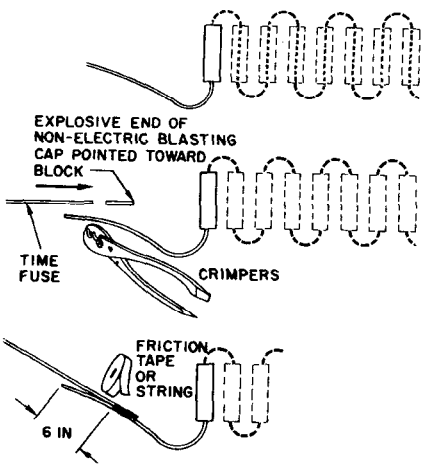


Figure 51. Nonelectric priming of M1 chain demolition block.

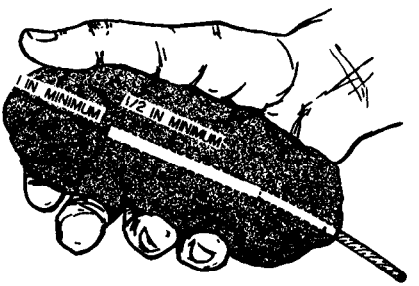


Figure 52. Nonelectric priming of molded plastic explosive.

ing is used either when a whole case is fired or when placed charges require no tamping.

a. End Priming Method.

(1) Punch a hole in the end of the cartridge (fig. 53).

(2) Insert a fused blasting cap.

(3) Tie the cap and fuse securely in the cartridge.

b. Weatherproof Priming Method.

(1) Unfold the wrapping at the folded end of the cartridge.

(2) Punch a hole in the exposed dynamite.

(3) Insert a fused blasting cap into the hole.

c. Side Priming Method (for Charges in Tamped Boreholes).

(1) Punch a hole in the cartridge about 1½ inches from one end (fig. 54).

(2) Point the hole so that the blasting cap when inserted, will be nearly parallel with the side of the cartridge and the explosive end of the cap will be at a point at about half the length of the cartridge.

(3) Insert a fused blasting cap into the hole.

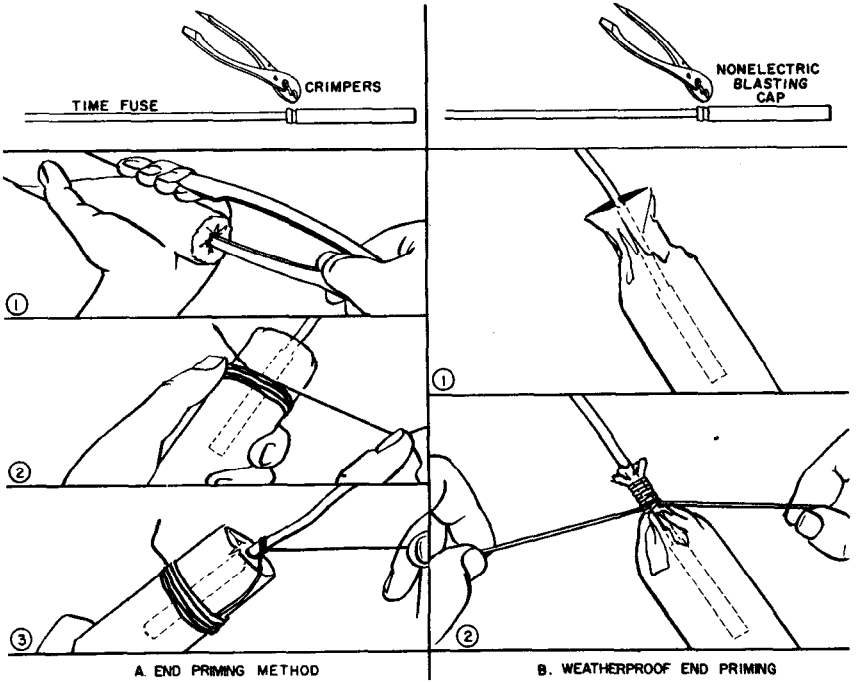


Figure 53. Nonelectric priming of dynamite at end.

(4) Close the wrapping.

(5) Fasten the cap and fuse securely with a string or length of tape (fig. 53).

(6) Apply weatherproofing compound to tie.

(4) Wrap a string tightly around the fuse and then around the cartridge, making two or three turns before tying the string (fig. 54).

(5) Moistureproof the primer by wrapping a string closely around the cartridge, extending it an inch on each side of the hole to cover it completely. Then cover the string with a water-repellent substance.

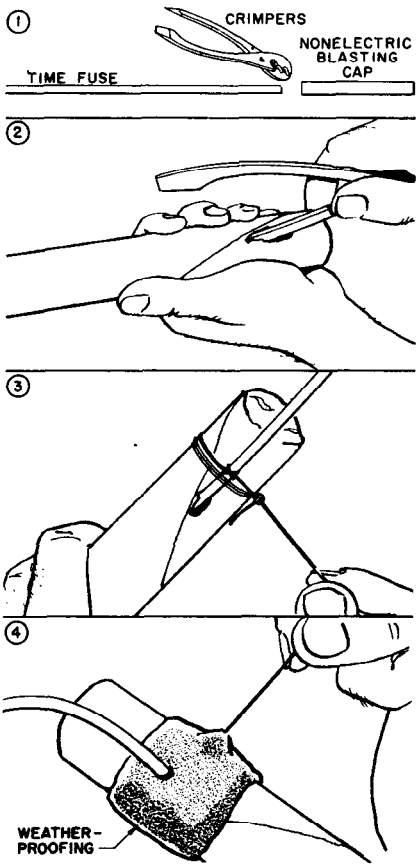


Figure 54. Nonelectric priming of dynamite at side.

48. Nonelectric Priming of Ammonium Nitrate and Nitramon Charges

The ammonium nitrate and nitramon charges are primed nonelectrically, as follows:

a. Place a fused blasting cap in the cap well on the side of the container (fig. 55).

b. Tie a string around the fuse and then around the cleat above the blasting cap.

Note. A primed block of TNT placed on top of the charge is recommended to insure positive detonation.

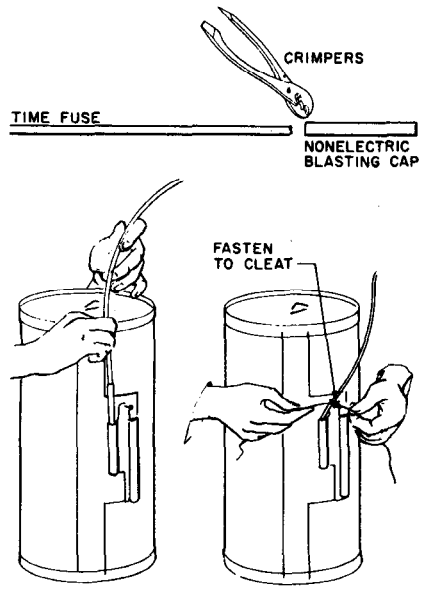


Figure 55. Nonelectric priming of ammonium nitrate and nitramon charges.

49. Nonelectric Priming of Special Charges

a. M2A3, M2A4, and M3 Shaped Charges. These charges may be primed nonelectrically by means of a fused cap and priming adapter as

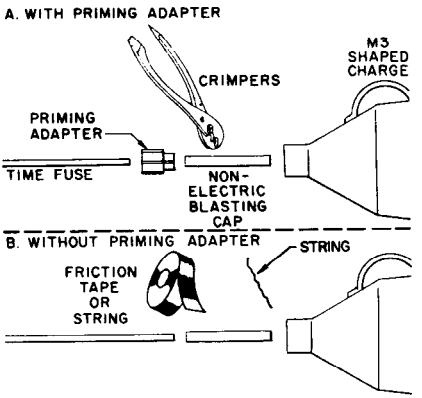


Figure 56. Nonelectric priming of shaped charges.

shown in figure 56. If a priming adapter is not available, the primer may be held in the cap well by a string or friction tape.

b. Bangalore Torpedo. The bangalore torpedo may be primed by assembling a length of time fuse and a nonelectric blasting cap in a priming adapter and screwing the assembly into the cap well of a torpedo section (fig. 57). A section may also be primed nonelectrically by a pull type firing device, with a nonelectric blasting cap crimped on the base, screwed into the cap well (fig. 57).

c. M118 Demolition Charge. This charge is commonly known as sheet explosive. It is packaged in four sheets $\frac{1}{4} \times 3 \times 12$ inches, with an adhesive on one side. It is primed by three methods (fig. 58):

(1) By inserting and holding a nonelectric blasting cap in a grove or notch cut in the charge or
(2) By placing the cap between two pieces of explosive or
(3) By placing the cap between an overlap in the charge.

50. Nonelectric Misfires

a. Prevention. Working on or near a misfire is the most hazardous of all blasting operations. A misfire should be extremely rare if these procedures are followed closely:

(1) Prepare all primers properly.
(2) Load charges carefully.
(3) Place primer properly.
(4) Perform any tamping operation with care to avoid damage to an otherwise carefully prepared charge.
(5) Fire the charge according to the proper technique.
(6) If possible, use dual firing systems

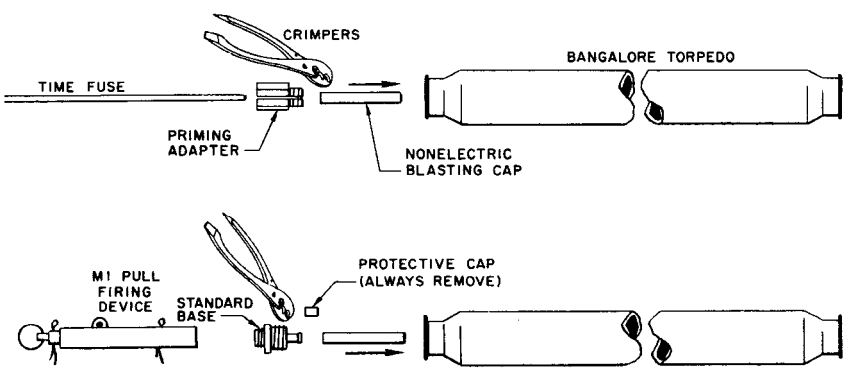


Figure 57. Nonelectric priming of bangalore torpedo.

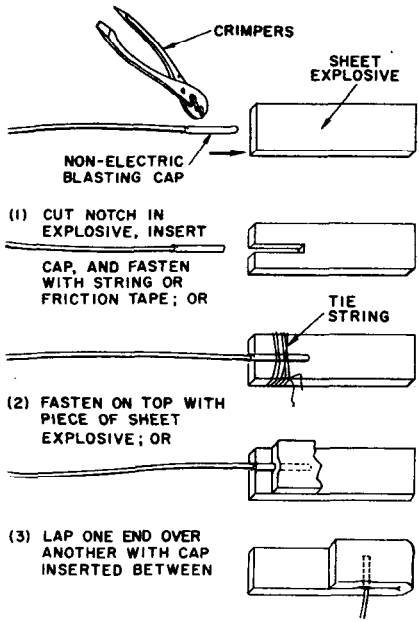

CRIMPERS
SHEET EXPLOSIVE
NON-ELECTRIC BLASTING CAP
(1) CUT NOTCH IN EXPLOSIVE, INSERT
CAP, AND FASTEN WITH STRING OR FRICTION TAPE; OR
TIE STRING
(2) FASTEN ON TOP WITH PIECE OF SHEET EXPLOSIVE; OR
(3) LAP ONE END OVER ANOTHER WITH CAP INSERTED BETWEEN

Figure 58. Nonelectric priming of sheet explosive.

(para 72–75). If both systems are properly assembled, the possibility of a misfire is reduced to a minimum.

b. The Handling of Nonelectric Misfires. Occasionally, despite all painstaking efforts, a nonelectric misfire will occur. Investigation and correction should be undertaken only by the man that placed the charge. For a charge primed with a nonelectric cap and time fuse, the procedure is as follows:

(1) Delay the investigation of the misfire at least 30 minutes after the expected time of detonation. This should be ample time for any delayed explosion to take place because of a defective powder train in the fuse. Under certain combat conditions, however, immediate investigation may be necessary.

(2) If the misfired charge is not tamped, lay a new primer at the side of the charge, without moving or disturbing it, and fire.

(3) If the misfired charge has no more than a foot of tamping, attempt to explode it by detonating a new 2-pound primer placed on top.

(4) If the misfired charge is located in a tamped borehole, or if the tamped charge is so situated as to make method (3) above impractical, remove the tamping by means of wooden or nonmetallic tools. Avoid accidentally digging into the charge. Also, the tamping may be blown out by means of a stream of compressed air or water if either is available. Constant checking of the depth of the borehole from the ground surface or the top of the charge during digging will minimize the danger of striking the charge. When the charge has been uncovered within 1 foot, insert and detonate a new 2-pound primer.

(5) An alternate method of reaching a deep misfired charge is to drill a new hole within one foot of the old one and to the same depth. A 2-pound primed charge is then placed in the new hole to detonate the misfired charge. Extreme care is required in drilling the new hole to avoid striking the old misfired charge or placing the new charge too far away to induce detonation.

SECTION II. ELECTRIC FIRING SYSTEM

51. Components and Assembly for Detonation

The electric firing system provides the electric spark or impulse to initiate detonation. The electric impulse travels from the power source through the lead wires to fire the cap.

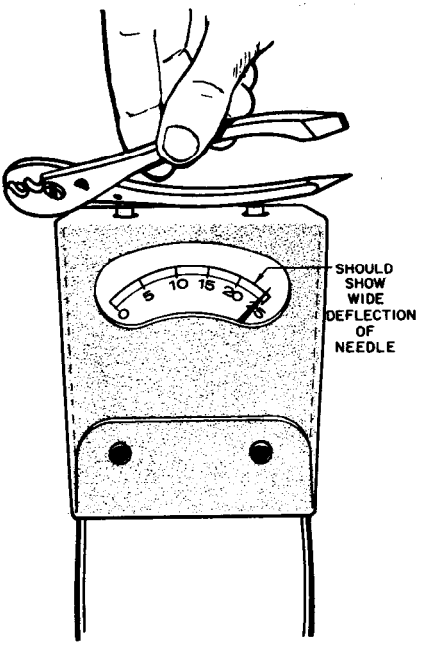


Figure 59. Testing the galvanometer.

The chief components of the system are the blasting cap, firing wire and reel, and the blasting machine. The preparation of the explosive charge for detonation by electrical means is called electric priming. Priming methods are described below.

a. Testing the Cap.

(1) Test the galvanometer (para 36) (fig. 59).

(2) Remove the short circuit shunt (prevents accidential firing) from the lead wires of the electric blasting cap (fig. 60).

(3) Touch one cap lead wire to one galvonmeter post and the other cap lead wire to the other. If the instrument registers a flowing current, the blasting cap is satisfactory; if not, the cap is defective and should not be used. During the test, *always point the explosive end of the blasting cap away from the body.*

b. Placing the Cap in the Explosive.

(1) Pass the lead wires through the slot of the adapter and pull the cap into place in the adapter.

(2) Insert the cap into the cap well of the explosive and screw the adapter into place.

(3) If a priming adapter is not available, insert the electric cap into the cap

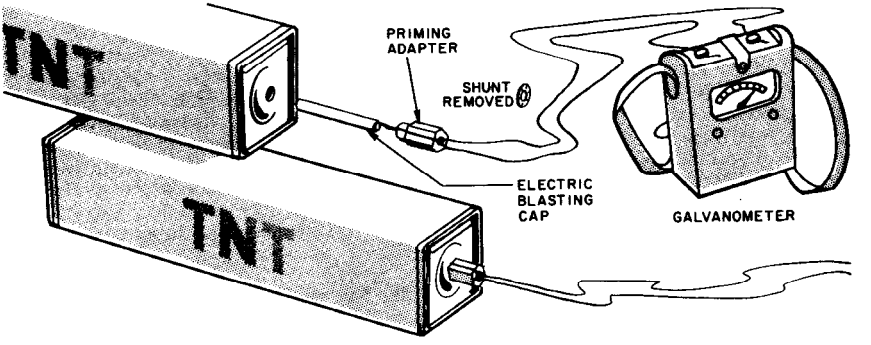


Figure 60. Assembling the electric primer.

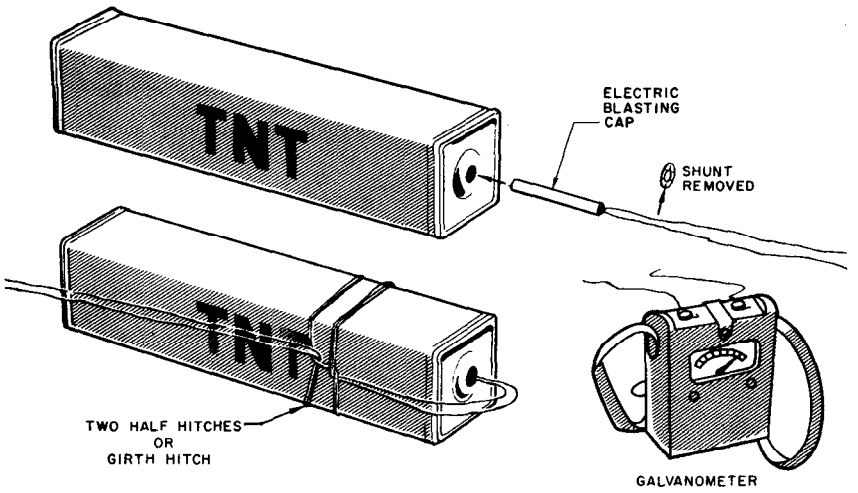


Figure 61. Electric priming without adapter.

well and tie the lead wires around the block by two half hitches or a girth hitch (fig. 61). (For details of electric priming of demolition blocks, see para 53.)

c. Wire Connections.

(1) Bare the two cap lead wires and the firing wires at the ends and splice them together to form two connections (para 52; fig. 62). Insulate these with friction tape.

(2) Check again with the galvonmeter, *a* (3), above.

(3) Fasten the two free ends of the firing wire to the two posts on the blasting machine.

d. Precautions.

(1) *Two or more caps.* If two or more special military blasting caps are connected in the same circuit, be sure that they are made by the same manufacturer. This is essential to prevent misfires, as blasting caps of different manufacturers have different electrical characteristics. Blasting caps of the same manufacturer may be identified by the label, color of the cap, or shape of the shunt. This is not true, however, of the M6 special electric blasting caps—all of which are made according to the same specification.

(2) *Firing the circuit.* For safety reasons, only one individual should be detailed to connect the blasting machine to the firing circuit and to fire the circuit. He should be responsible for the care of the blasting machine at all times during blasting activities. He also should either connect the blasting wires in the circuit or check their connection by on-the-spot visual examination.

52. Splicing Electric Wires

Insulated wires, before splicing, must have the insulating material stripped from the ends, exposing about 3 inches of bare wire (fig. 62).

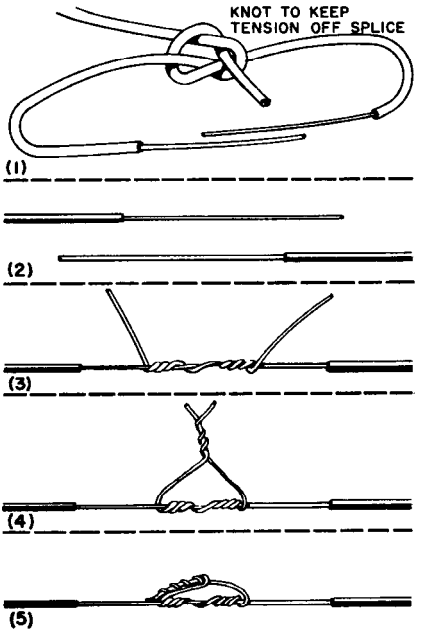


Figure 62. Splicing two wires (Western Union "pigtail" splice).

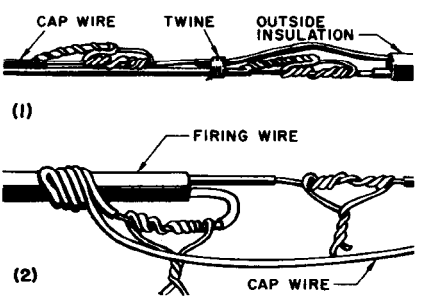


Figure 63. Splicing two pairs of wires.

All enamel also must be removed from the bared ends by carefully scraping them with the back of a knife blade or other suitable tool, but not nicking, cutting, or weakening them. Stranded wires, after scraping, should be twisted tightly.

a. Two Wires. Two wires, having been prepared as described above, may be spliced as shown in figure 62. This is called the Western Union "pigtail" splice.

b. Two Pairs of Wires. Join one pair of electrical conductors to another pair by splicing the individual wires to one another (one of one pair to one of another pair, and the second of one pair to the second of the other). In order to prevent a short circuit at the point of splice, stagger the two separate splices and tie with twine or tape as in (1), figure 63. An alternate method of preventing a short circuit at the point of splice is shown in (2), figure 63, where the splices are separated, not staggered.

c. Protection of Splices. Protect all bare wire splices in wiring circuits to prevent their short-circuiting to the ground or to each other. Whenever possible, insulate them from the ground or other conductors by wrapping them with friction tape or other electric insulating tape. This is particularly necessary when splices are placed under wet tamping. Circuit splices, not taped or insulated, lying on moist ground, must be supported on rocks, blocks, or sticks so that only the insulated portion of the wires touches the ground. They may be protected from damage from pull by typing the ends in an overhand knot, allowing sufficient length for easy splicing ((1), fig. 62)).

53. Electric Priming of Demolition Blocks

a. Blocks with Threaded Cap Wells.

(1) *With priming adapter.* Priming adapters simplify the priming of military explosives with threaded cap wells. A slot running the full length off the adapter is provided for easy insertion of the lead wires. The end of the adapter that secures the cap fits tne internal thread of threaded cap wells in military explosives. The priming components are assembled as shown in figure 64.

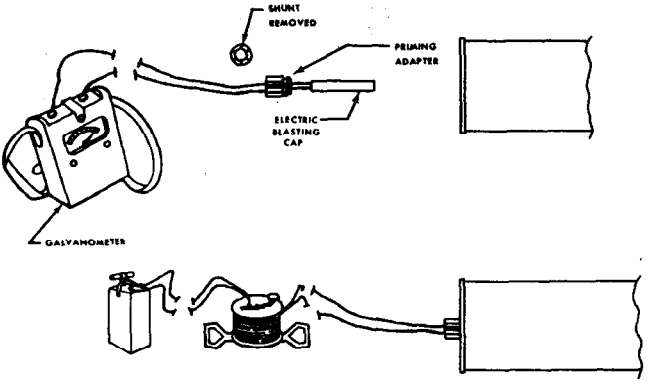


Figure 64. Electric priming of demolition block with priming adapter.

(2) *Without priming adapter.* If a priming adapter is not available and the demolition block has a threaded cap well, insert the electric cap into the cap well and tie the lead wires around the block by two half-hitches or a girth hitch. Leave a small portion of slack wire between the blasting cap and the tie to prevent any pull on the blasting cap (fig. 61).

b. Blocks Without Cap Wells. If the demolition blocks have no threaded cap wells proceed as follows:

(1) Make a hole in the end *large enough to receive the cap* with a pointed nonspark instrument or the pointed leg of the crimper handle (fig. 65).

(2) Insert the cap in this cap well and tie the cap wires around the block by two half hitches or a girth hitch. To prevent pull on the cap, always leave a small portion of slack wire between the blasting cap and the tie.

Note. Never try to force a blasting cap into an expedient fuse well that is too small to admit it easily.

54. Electric Priming of M1 Chain Demolition Block

The M1 chain demolition block is primed elec-

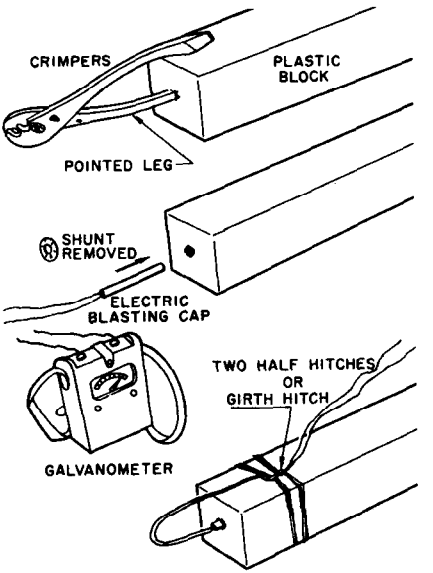


Figure 65. Electric priming of plastic explosive without cap well.

trically by fastening an electric blasting cap to one of the free ends of the detonating cord chain with friction tape or by some other method. *The explosive end of the cap should point toward the chain demolition blocks.* The firing of the blasting cap detonates the cord, which in turn detonates the entire chain.

55. Electric Priming of Plastic Explosives (C3 and C4)

a. The M5 (C3) and M5A1 (C4) demolition blocks with threaded cap wells or recesses and with and without priming adapters and the M3 (C3) demolition block without a threaded cap well are primed electrically as shown in paragraph 53 and figures 61, 64, and 65.

b. Plastic explosive removed from the container is primed electrically by molding it around the blasting cap (fig. 66). The explosive must extend at least 1 inch at the explosive end of the blasting cap and ½ inch at the sides to insure detonation.

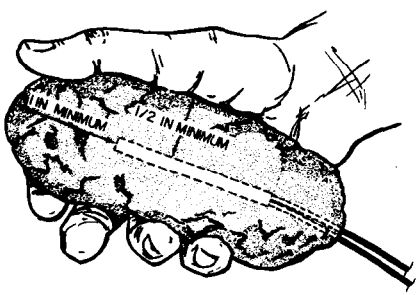


Figure 66. Electric priming of molded plastic explosive.

56. Electric Priming of Dynamite

Dynamite cartridges may be primed electrically at either end or at the side. End priming is used either when a whole case is fired or when placed charges require no tamping.

a. End Priming Method.

(1) Punch a hole in the end of the cartridge (fig. 67).

(2) Insert an electric blasting cap.

(3) Tie the lead wires around the cartridge with two half hitches.

b. Side Priming Method.

(1) Punch a hole in the cartridge about 1½ inches from one end (fig. 68).

(2) Point the hole so that the electric blasting cap, when inserted, will be nearly parallel with the side of the cartridge and the explosive end of the cap will be at a point at about half the length of the cartridge.

(3) Insert the blasting cap into the hole.

(4) Tie the lead wires around the cartridge with two half hitches or fasten with a string or tape.

57. Electric Priming of Ammonium Nitrate and Nitramon Charges

The electric blasting cap is placed in the cap well and the lead wires are looped around the cleat (fig. 69).

58. Electric Priming of Special Charges

a. M2A3, M2A4, and M3 Shaped Charges. These may be primed electrically by means of an electric blasting cap and a priming adapter as shown in figure 70. If a priming adapter is not available, the electric cap may be held in place by a length of string or friction tape.

b. Bangalore Torpedo. The bangalore torpedo may be primed electrically by assembling a blasting cap and priming adapter and screwing the assembly into the cap well of a torpedo section (fig. 71).

c. M118 Demolition Charge. This charge, commonly known as sheet explosive (fig. 72), is packaged in four sheets ¼ x 3 x 12 inches, with an adhesive on one side. It is primed by—

(1) Inserting and holding an electric blasting cap in a groove or notch cut in the charge, or

(2) Placing the cap between two sheets or pieces of explosive or,

(3) Placing the cap between an overlap of the charge.

59. Series Circuits

a. Common Series. This is used for connecting two or more charges fired electrically by a blasting machine (fig. 73). A common series circuit is prepared by connecting one

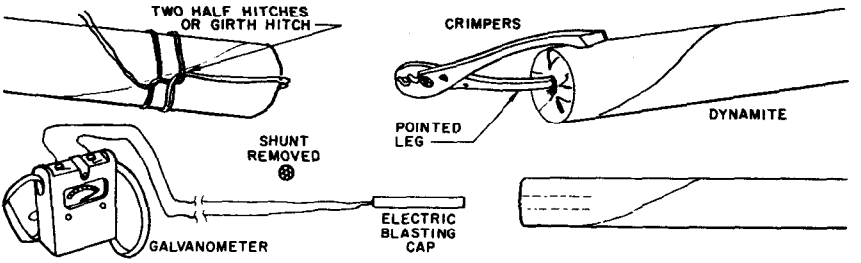


Figure 67. Electric priming of dynamite at end.

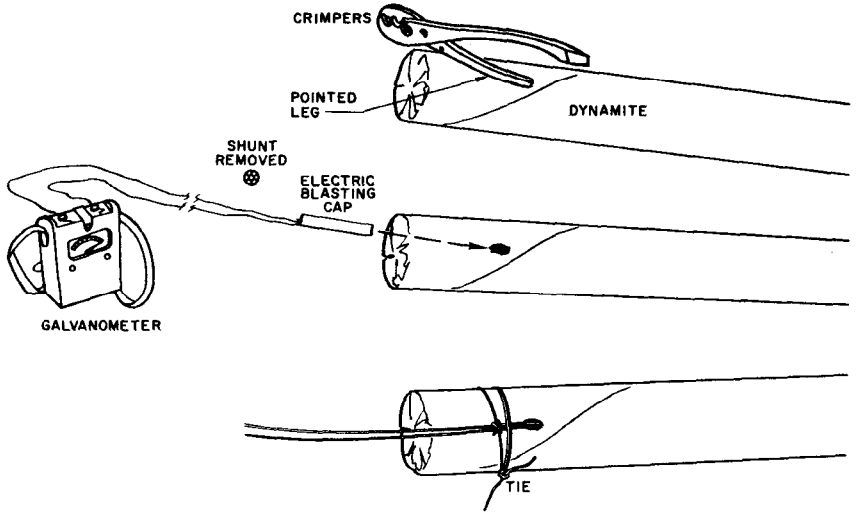


Figure 68. Electric priming of dynamite at side.

blasting cap lead wire from the first charge to one lead wire in the second charge and so on until only two end wires are free, then connecting the free ends of the cap lead wires to the ends of the firing wire. Connecting wires (usually annunicator wire) are used when the distance between blasting caps is greater than the length of the usual cap lead wires.

b. "Leapfrog" Series. The "leapfrog" method of connecting caps in series (fig. 73) is useful for firing ditching charges or any long line of charges. It consists of omitting alternate

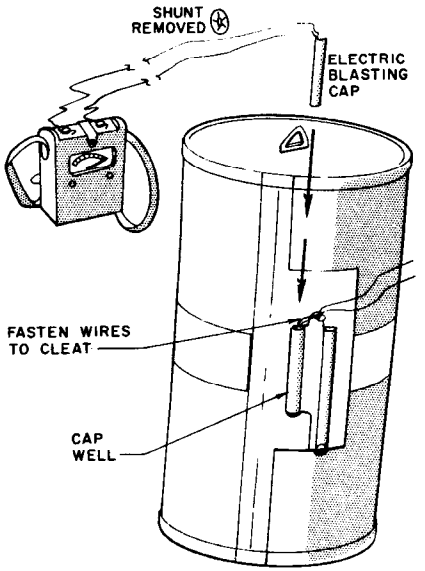


Figure 69. Electric priming of ammonium nitrate and nitramon charges.

charges on the way and then connecting them to form a return path for the electric impulse to reach the other lead of the firing wire. This brings both end wires out at the same end of the line of charges, and thus eliminates laying a long return lead from the far end of the line of charges back to the firing wire.

60. Testing Electric Wires and Circuits

a. Firing Wires May be Tested as Follows:

(1) Check galvanometer by holding a piece of metal across its terminals (para 36; fig. 59).

(2) Separate the firing wire at both ends, and touch those at one end to the galvanometer posts. The needle should not move. If it does, the firing wire has a short circuit (fig. 74); or

(3) Twist the wires together at one end and touch those at the other to the galvanometer posts. This should cause a wide deflection in the needle. (See note at end of *c*(2), below). No movement of the needle indicates a break; a slight movement, a point of high resistance.

Note. Firing wire may be tested on the reel, *but should be tested again after unreeling, which may separate broken wires unnoticed when reeled.*

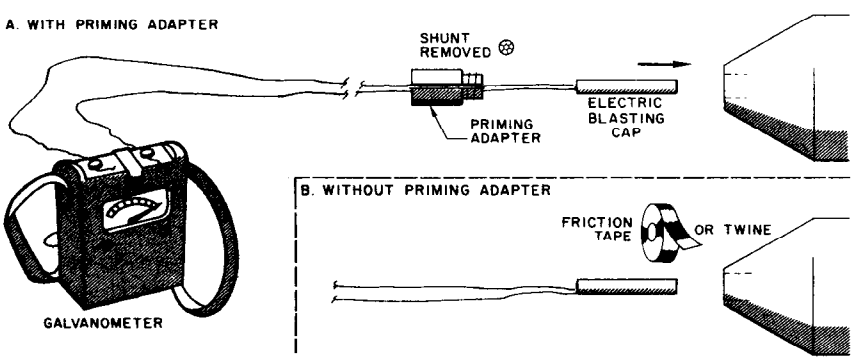


Figure 70. Electric priming of shaped charges.

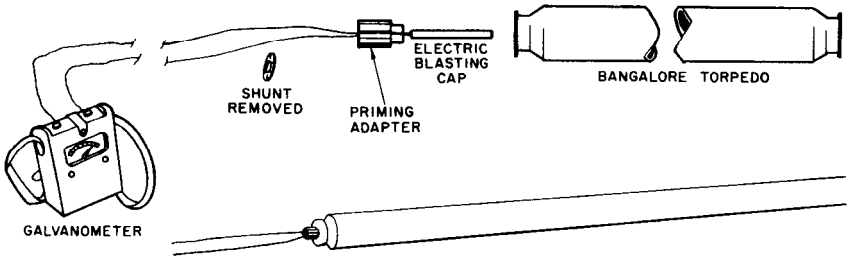


Figure 71. Electric priming of bangalore torpedo.

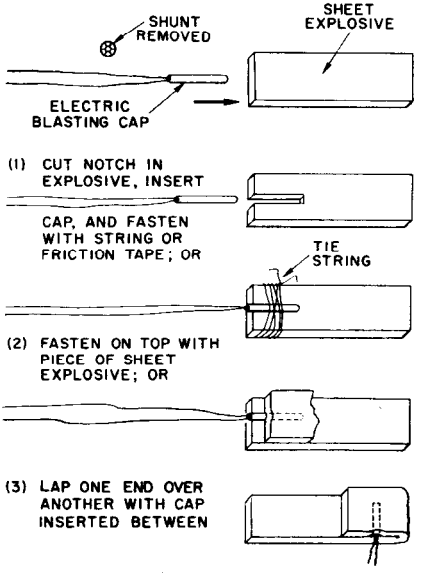


Figure 72. Electric priming of sheet explosive.

b. Series Circuits May be Tested as Follows:

(1) Connect charges as shown in figure 75.

(2) Touch the free ends of the lead wires to the galvanometer posts. This should cause a wide deflection of the needle.

c. The Entire Circuit May be Tested as Follows:

(1) Splice firing wires to series circuit and move to firing position.

(2) Touch free ends of firing wire to galvanometer posts (fig. 76). This should cause a wide deflection of the needle. If not, the circuit is defective. If defective, shunt wires. Then go down range and recheck the circuit, repeating *a*(2), (3) and *b*(1), (2) above. If a splice is found defective, resplice the wires. If a cap is found defective, replace it. Then test the entire circuit again to make sure that all breaks have been located before attempting to fire the charge.

Note. To get a "wide deflection of the needle" the galvanometer battery should be in good condition.

61. Electric Misfires

a. Prevention of Electric Misfires. In order to prevent misfires, make one demolition specialist responsible for all electrical wiring in a demolition circuit. He should do all splicing to be sure that—

(1) All blasting caps are included in the firing circuit.

(2) All connections between blasting cap wires, connecting wires, and firing wires are properly made.

(3) Short circuits are avoided.

(4) Grounds are avoided.

(5) The number of blasting caps in any

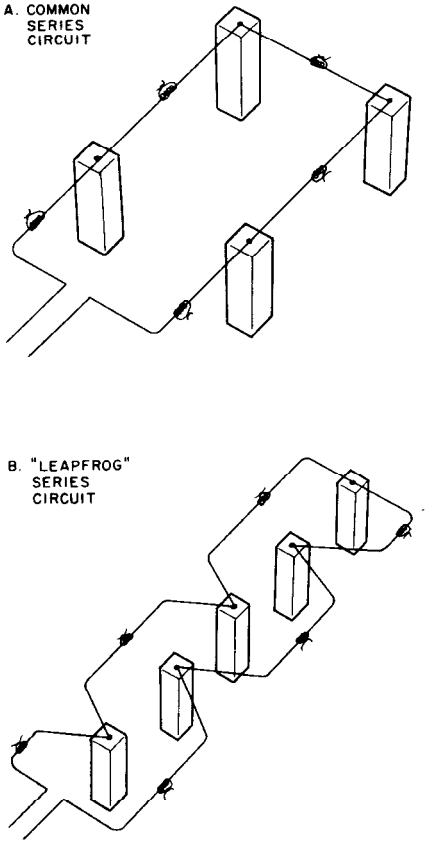


Figure 73. Series circuits.

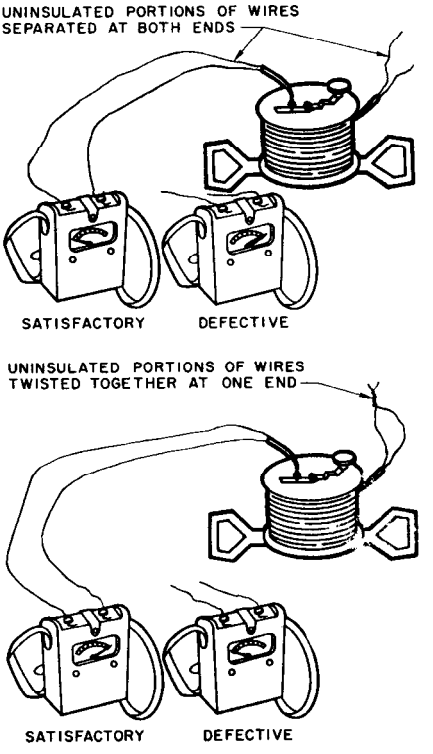


Figure 74. Testing firing wire.

circuit does not exceed the rated capacity of the power source on hand.

b. Cause of Electric Misfires. Common specific causes of electric misfires include—

(1) Inoperative or weak blasting machine or power source.

(2) Improperly-operated blasting machine or power source.

(3) Defective and damaged connections, causing either a short circuit, a break in the circuit, or high resistance with resulting low current.

(4) Faulty blasting cap.

(5) The use in the *same circuit* of old type (J–2) special blasting caps made by different manufacturers.

(6) The use of more blasting caps than the power source rating permits.

c. Handling Electric Misfires. Because of the hazards of burning charges and delayed ex-

plosions, electric misfires must be handled with extreme caution. A burning charge may occur with the use of electric as well as nonelectric caps. Misfires of charges primed with detonating cord fired by electric blasting caps are handled as described in paragraph 71. If the charge is dual-primed electrically and below ground, wait 30 minutes before investigating to make sure that the charge is not burning; or if dual-primed above ground, wait 30 minutes before investigating. On the other hand, if the electric misfire is above ground and the charge is not dual-primed, investigate immediately. If the system is below ground and not dual-primed, proceed as follows—

(1) Check the firing wire connection to the blasting machine or power source terminals to be sure that the contacts are good.
(2) Make two or three more attempts to fire the circuits.
(3) Attempt to fire again, using another blasting machine or power source.
(4) Disconnect the blasting machine firing

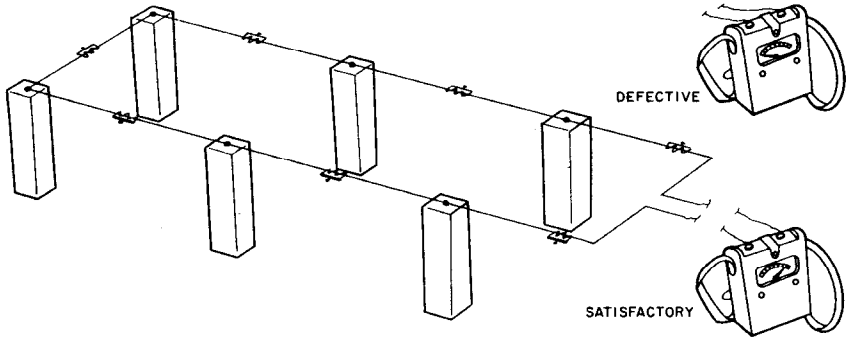


Figure 75. Testing a series circuit.

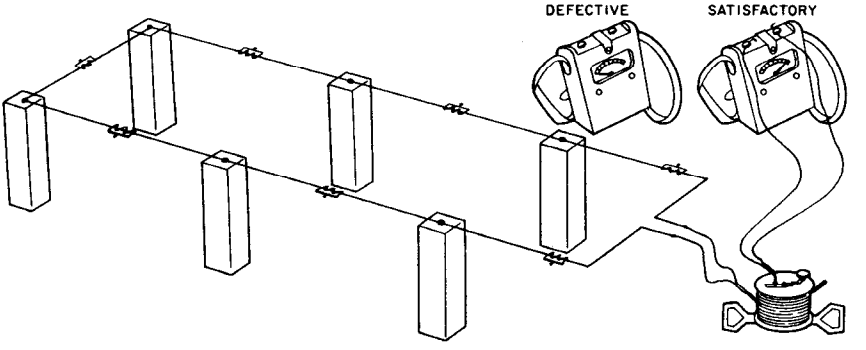


Figure 76. Testing the entire circuit.

wire and wait 30 minutes before further investigation. Before moving on to the charge site, be sure that the firing wires at the power source end of the circuit are shunted to avoid any possible static electric detonation.

(5) Check the entire circuit, including the firing wire, for breaks and short circuits.

(6) If the fault is not above ground, remove the tamping material very carefully from the borehole to avoid striking the electric blasting cap.

(7) Make no attempt to remove either the primer or the charge.

(8) If the fault is not located by the removal of the tamping material to within 1 foot of the charge, place a new electric primer and 2 pounds of explosive at this point.

(9) Disconnect the blasting cap wires of the original primer from the circuit.

(10) Connect the wires of the new primer in their place.

(11) Replace the tamping material.

(12) Initiate detonation. Detonation of the new primer will fire the original charge.

Note. In some cases it may be more desirable or expedient to drill a new hole within a foot of the old one at the same depth to avoid accidental detonation of the old charge and then place and prime a new 2-pound charge.

62. Premature Detonation by Induced Currents and Lightning

a. Induced Currents. The premature detonation of electric blasting caps by induced radio frequency (RF) current is possible. Table VII, showing the minimum safe distance *versus* transmitter power, indicates the distance beyond which it is safe to conduct electrical blasting even under the most adverse conditions. Mobile type transmitters are prohibited within 150 feet of any electric blasting caps or electrical blasting system. If blasting distances are less than those shown in table VII, the only safe procedure is to use a nonelectric system, which cannot be prematurely detonated by RF currents. If, however, the use of the electric system is necessary, follow precautions given in AR 385–63.

Table VII. Minimum Safe Distance for RF Transmitters

Fixed transmitters	
Transmitter power (watts)	Minimum distance (ft.)
5–25	100
25–50	150
50–100	220
100–250	350
250–500	450
500–1,000	650
1,000–2,500	1000
2,500–5,000	1500
5,000–10,000	2200
10,000–25,000	3500
25,000–50,000	5000
50,000–100,000	7000

b. Lightning. Lightning is a hazard to both electric and nonelectric blasting charges. A strike or a nearby miss is almost certain to initiate either type of circuit. Lightning strikes, even at remote locations, may cause extremely high local earth currents and shock waves that may initiate electrical firing circuits. The effects of remote lightning strikes are multiplied by proximity to conducting elements, such as those found in buildings, fences, railroads, bridges, streams, and underground cables or conduit. Thus, the only safe procedure is to suspend all blasting activities during electrical storms.

Section III. DETONATING CORD PRIMING

63. Components

a. Of all primers for explosive charges, detonating cord is probably the most versatile and in many cases the most easily installed. It is especially applicable for underwater and underground blasting, as the blasting cap of the initiating system may remain above the water or ground.

b. The detonating cord primer consists, generally, of a length of detonating cord and the means of detonation which may be an electric blasting cap initiated by a blasting machine or

power source or a nonelectric blasting cap initiated by a fuse lighter and a length of time fuse. The blasting cap of either the electric or nonelectric system is attached to the free end of the detonating cord by means of a length of string, wire, or friction tape. Detonating cord primers are usually tied around the explosive block; however, in situations where a close contact between the explosive block and the target is required, a nonelectric blasting cap is crimped on the end of the detonating cord and placed in the cap well.

64. Priming Demolition Blocks

a. Common Method (A, fig. 77)

(1) Lay one end of a 4-foot length of detonating cord at an angle across the explosive block as shown in A, figure 77.

(2) Wrap the running end three times over the end laid at an angle and around the block, and on the fourth turn, slip the running end under the three wraps parallel with the other end and then draw tight.

(3) Attach an electric or nonelectric firing system.

b. Alternate Method No. 1 (*B, fig. 77*).

(1) Tie the detonating cord around the explosive block (on top of the booster, if present) with a clove hitch with two extra turns as shown in B, figure 77.

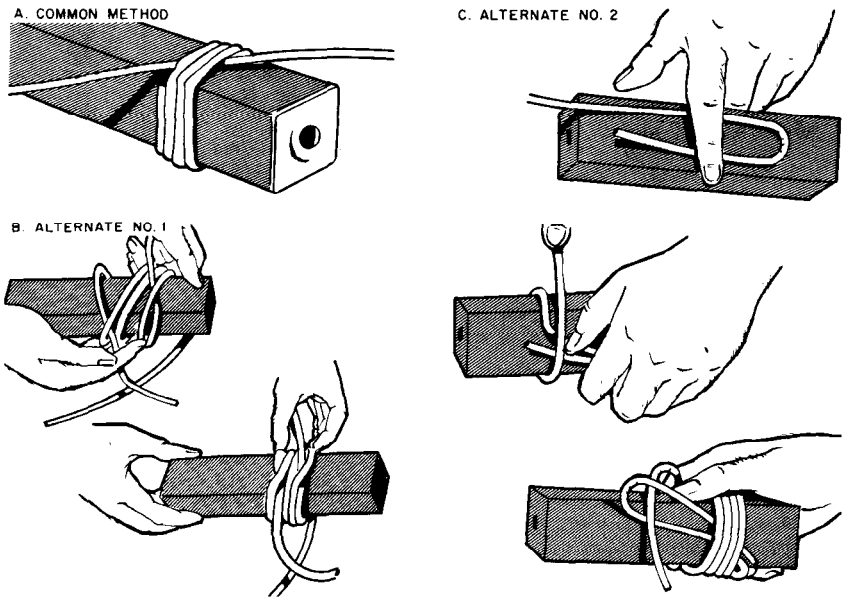


Figure 77. Detonating cord priming of demolition blocks.

The cord must fit snugly against the blocks and the loops be pushed close together.

(2) Attach an electric or nonelectric firing system.

c. Alternate Method No. 2 (C, fig. 77)

(1) Place a loop of detonating cord on the explosive block as in C, figure 77.

(2) Wrap the detonating cord four times around the block and finally draw the running end through the loop.

(3) Pull until tight.

(4) Attach an electric or nonelectric firing system.

Note. This alternate method is more applicable to *short* than to long detonating cord branch lines or primers.

65. Priming M1 Chain Demolition Block

The M1 chain demolition block has detonating cord running lengthwise through the individual blocks. If an additional length of detonating cord is required, it is connected to the detonating cord of the chain with a clip or square knot. The additional length of detonating cord may be initiated by means of an electric blasting cap and firing device or an nonelectric blasting cap, length of time fuse, and a fuse lighter. If the cord running through the blocks is cut too closely to the end block to permit such a connection, the additional length of detonating cord may be fastened by a clove hitch with two extra turns near the end of the block over the booster (fig. 78).

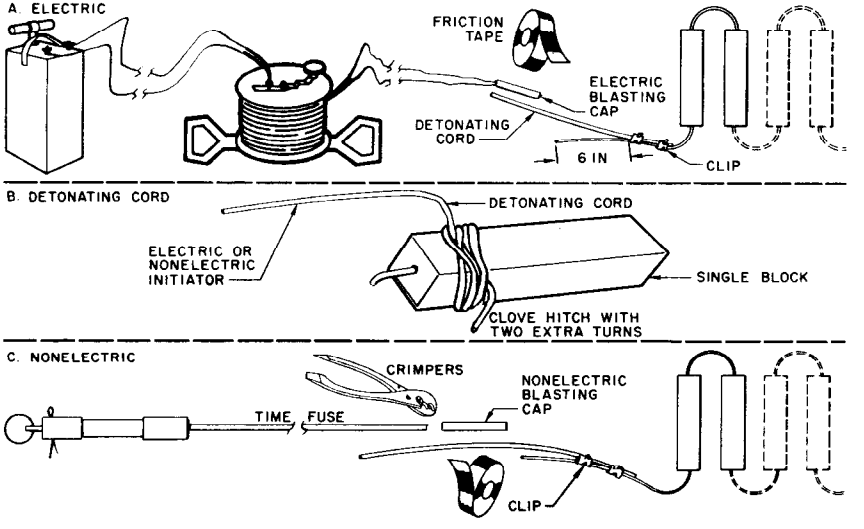


Figure 78. Detonating cord priming of M1 chain demolition block.

66. Priming Dynamite

For use chiefly in boreholes, ditching, or removal of stumps, dynamite is primed by lacing the detonating cord through it. This is done by punching three or four equally-spaced holes through the dynamite cartridge, running the detonating cord back and forth through them, and securing it with a knot or by lacing as shown in figure 79.

67. Priming Plastic Explosive (C3 and C4)

Compositions C3 and C4 when removed from the package are primed with detonating cord, as follows:

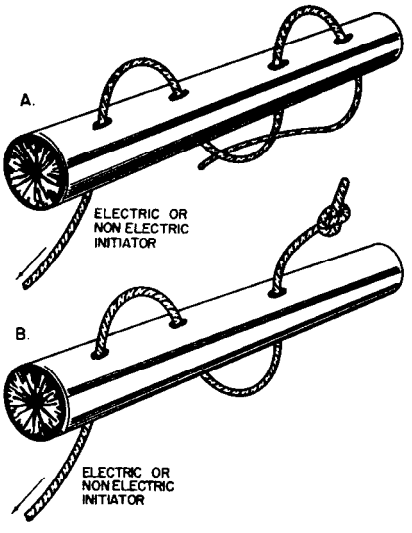


Figure 79. Detonating cord priming of dynamite.

a. Take a 10-inch bight at the end of the detonating cord and tie an overhand knot (fig. 80).

b. Mold the explosive around the knot, leaving at least ½ inch of explosive on all sides and at least 1 inch on each end.

Note. Another method is to cut the block longitudinally, then insert the knot, and fasten with tape or string as shown in figure 80.

68. Priming Ammonium Nitrate and Nitramon Charges

To prime ammonium nitrate and nitramon cratering charges with detonating cord:

a. Pass the detonating cord through the tunnel provided on the one side of the can (fig. 81).

b. Tie an overhand knot on the portion passed through about 6 inches from the end.

c. Attach an electric or nonelectric firing system (fig. 81).

d. For dual priming any firing system may be used for the additional charge—a 1-pound block of TNT—to insure detonation (para 21*c*).

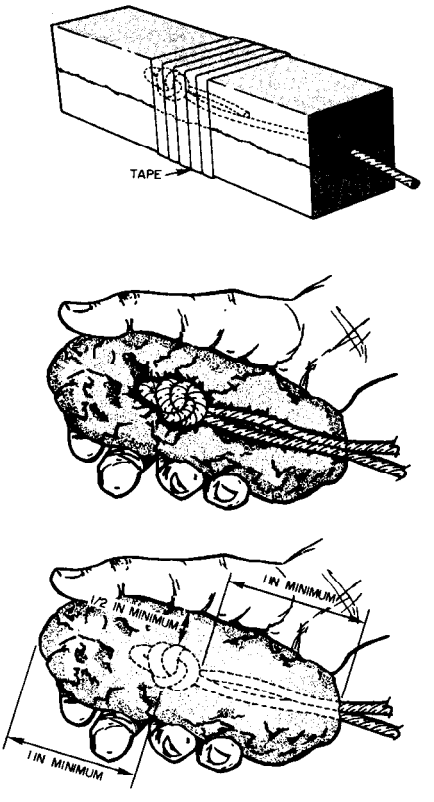


Figure 80. Detonating cord priming of plastic explosive.

69. Priming Special Charges

a. Shaped Charges. M2A3 and M3 shaped charges are primed with a length of detonating cord with a nonelectric blasting cap crimped on (fig. 82), and detonated with an electric or nonelectric firing system.

b. Bangalore Torpedo. A bangalore torpedo may be primed by attaching a length of detonating cord by wrapping six turns directly over

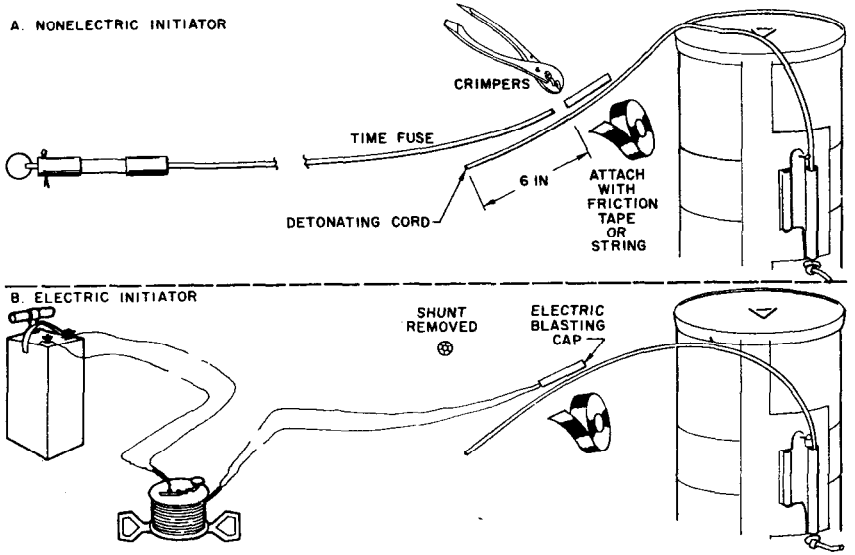


Figure 81. Detonating cord priming of ammonium nitrate and nitramon charges.

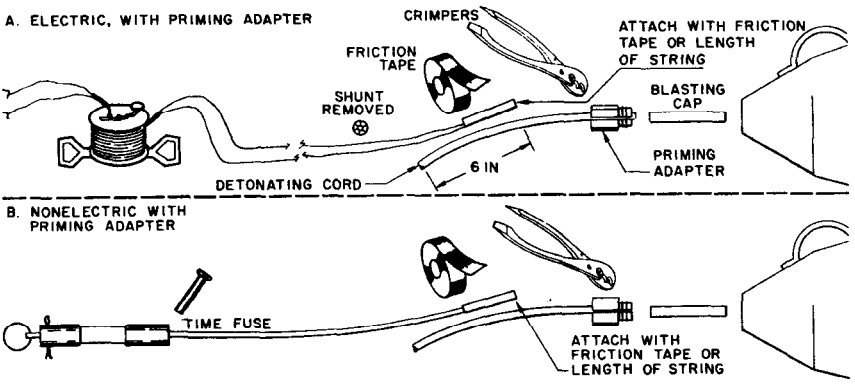


Figure 82. Detonating cord priming of shaped charge.

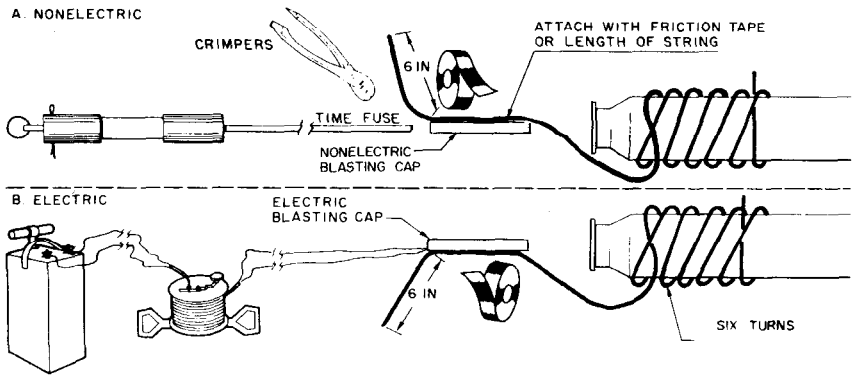


Figure 83. Detonating cord priming of bangalore torpedo.

the booster (fig. 83) and detonating with an electric or nonelectric firing system.

c. Pole Charges. Detonating cord assemblies are excellent primers for pole charges, as the detonating cord spans the distance from the charge to a position where the electric or nonelectric firing system is accessible to the blaster. The method of priming with a dual electric primer is shown in figure 84.

70. Assemblies and Connections

a. Detonating Assemblies.

(1) *Nonelectric.* This detonating assembly consists of a length of detonating cord (approximately 2 feet), a nonelectric blasting cap, a length of time fuse, and a fuse lighter. The blasting cap is crimped to the time fuse and then fastened to the detonating cord (A, fig. 85). The fuse lighter is then fastened to the time fuse. The length of time fuse depends on the time required for the blaster to reach safety after lighting the fuse.

(2) *Electric.* The electric detonating assembly is a length of detonating cord (approximately 2 feet) with an electric blasting cap attached (B, fig. 85).

(3) *Attachment of assembly to system.* The free end of the detonating cord is fastened to the main line by a clip or a square knot as shown in figure 85.

(4) *Advantages.* Many advantages may be gained by th euse of these primers —they may be made up in advance, thus saving time at the target, which is a great advantage when time is a critical factor; and they permit the person in charge to attach the initiating system and function it as he desires, giving him complete control of the operation. Also, a detonating cord loop is useful in attaching two or or more ring mains to a single priming assembly; and a single electric or nonelectric blasting cap properly fastened to two detonating cord mains by a string, wire, or piece of cloth will detonate both (fig. 86).

b. Detonating Cord Connections. A detonating cord clip (fig. 26) or square knot pulled tight is used to splice the ends of the detonating cord. At least a 6-inch length should be left free at both sides of the knot (fig. 87). When fabric is used to cover the detonating cord, the fabric must not be removed. The knot should not be placed in water or in the ground unless the charge is to be fired immediately.

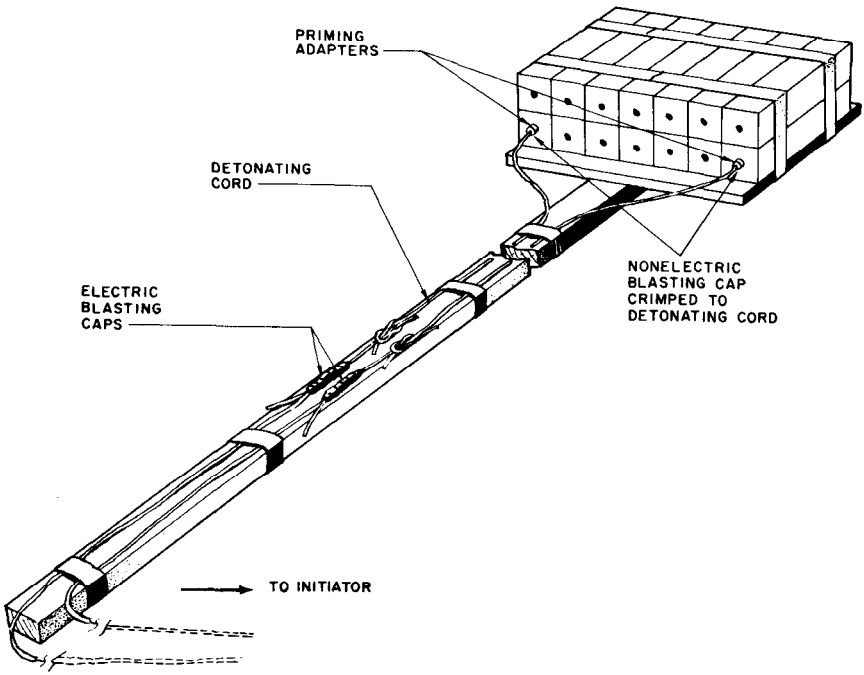


Figure 84. Detonating cord priming of pole charge.

c. Branch Line Connections. A branch line is fastened to a main line by means of a clip (fig. 26) or a girth hitch with one extra turn (fig. 88). The angle formed by the branch line and the cap end of the main line should not be less than 90° from the direction from which the blast is coming; at a smaller angle, the branch line may be blown off the main line without being detonated. At least 6 inches of the running end of the branch line is left free beyond the tie.

d. Ring Main. A ring main is made by bringing the main line back in the form of a loop and attaching it to itself with a girth hitch and one extra turn (fig. 89). This, if of sufficient length, will detonate an almost unlimited number of charges. The ring main makes the detonation of all charges more positive because the detonating wave approaches the branch lines from both directions and the charges will be detonated even when there is one break in the ring main. Branch lines coming from a ring main should be at a 90° angle. Kinks in lines should be avoided and curves and angles should be gentle. Any number of branch lines may be connected to the main line, but a branch line is never connected at a point where the main line is spliced. In making detonating cord branch line connections, avoid crossing lines. However, if this is necessary, be sure

that the detonating cords are at least a foot apart in places where they cross, or they will cut each other and possibly destroy the firing system.

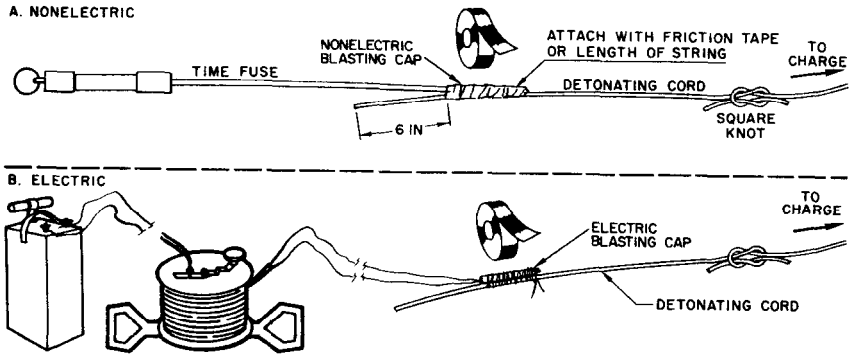


Figure 85. Electric and nonelectric assemblies attached to main line.

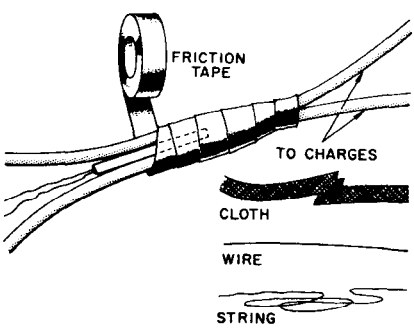


Figure 86. Fastening two lines of detonating cord to a single blasting cap assembly.

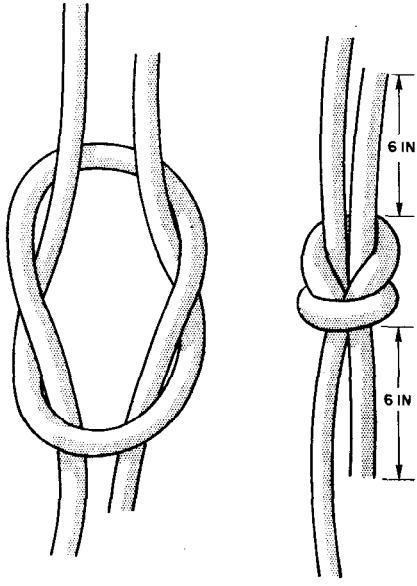


Figure 87. Square knot connections.

71. Handling Detonating Cord Misfires

a. Failure of Nonelectric Blasting Cap. If a nonelectric blasting cap initiator attached to detonating cord fails to function, delay the investigation for at least 30 minutes. Then cut the detonating cord main line between the blasting cap and the charge, and fasten a new blasting cap initiator on the detonating cord.

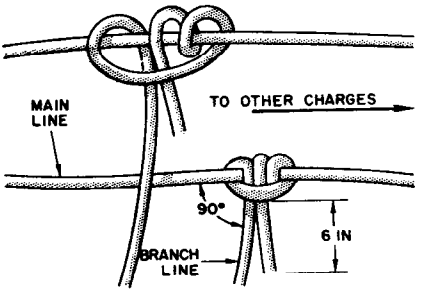


Figure 88. Girth hitch with one extra turn connecting branch line to main line.

b. Failure of Electric Blasting Cap. If an exposed electric blasting cap fastened to detonating cord fails to fire, disconnect the blasting machine immediately and investigate. Test the blasting circuit for any breaks or short circuit. If necessary, replace the original blasting cap.

c. Failure of Detonating Cord. If detonating cord fails to function at the explosion of an exposed electric or nonelectric blasting cap, investigate immediately. Attach a new blasting cap to the detonating cord, taking care to fasten it properly.

d. Failure of Branch Line. If the detonating cord main line detonates but a branch line fails, fasten a blasting cap to the branch line and fire it separately.

e. Failure of Charge to Explode. If the detonating cord leading to a charge detonates but the charge fails to explode, when above ground, delay investigation until it is certain that the charge is not burning; but when below ground, wait 30 minutes. If the charge is intact, insert a new primer. If the charge is scattered by the detonation of the original detonating cord, reassemble as much of the original charge as possible, place a new charge if necessary, and reprime. Make every attempt possible to recover all explosives scattered by misfire, particularly those used in training exercises.

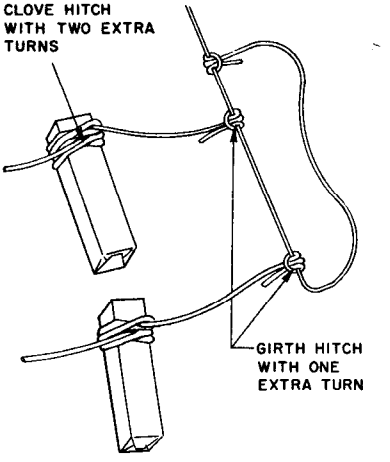


Figure 89. Ring main with branch lines.

Section IV. DUAL FIRING SYSTEMS

72. Reduction of Misfire Risks

a. The use of a dual firing system greatly increases the probability of successful firing. In combat, misfires may cause the loss of battles; in training, they cause the loss of valuable time and endanger the lives of those that investigate them. It is necessary to take every possible precaution to avoid misfires of demolition charges.

b. The failure of firing circuits is most frequently the cause of demolition misfires. Thus a dual firing system should be used whenever time and materials are available. It may consist of two electric systems, two nonelectric systems, or one electric and one nonelectric system. The systems must be entirely independent of each other and capable of firing the same charge.

73. Nonelectric Dual Firing System

This consists of two independent nonelectric systems for firing a single charge or set of

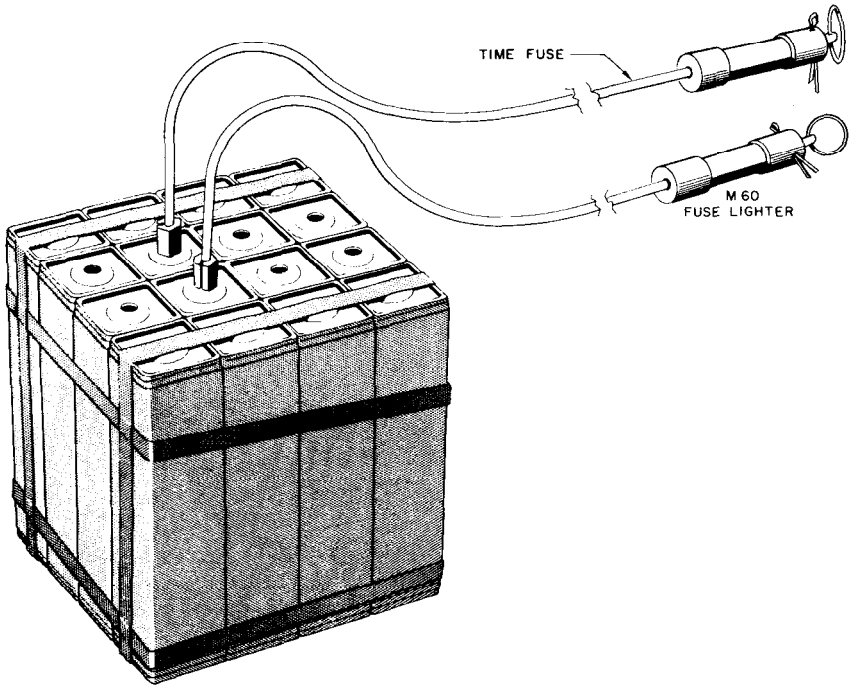


Figure 90. Nonelectric dual firing system.

charges. If two or more charges are to be fired simultaneously, two detonating cord ring mains are laid out, and a branch line from each charge is tied into each ring main. Figures 90 and 91 show the layouts for nonelectric dual firing systems.

74. Electric Dual Firing System

This dual firing system consists of two independent electric circuits, each with an electric blasting cap in each charge, so that the firing of either circuit will detonate all charges. Thus, each charge must have two electric primers. The correct layout is shown in figure 92. The firing wires of the two circuits should be kept separated so that both will not be cut by a single bullet or a single shell fragment. The firing points also should be at two separate locations.

75. Combination Dual Firing System

The combination dual firing system requires an electric and nonelectric firing circuit (fig. 93). Each charge has an electric and nonelectric primer. Both the electric and nonelectric circuits must be entirely independent of each other. The nonelectric system should be fired first.

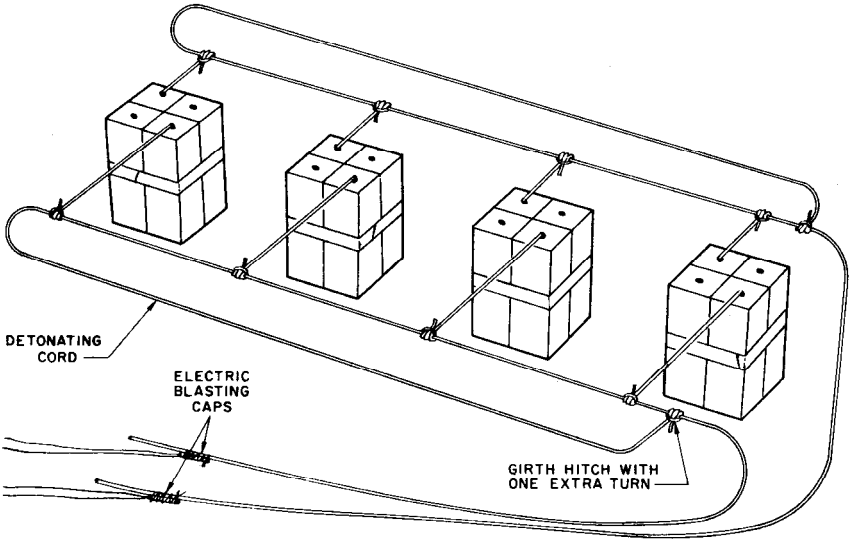


Figure 91. Dual detonating cord priming, using two ring mains.

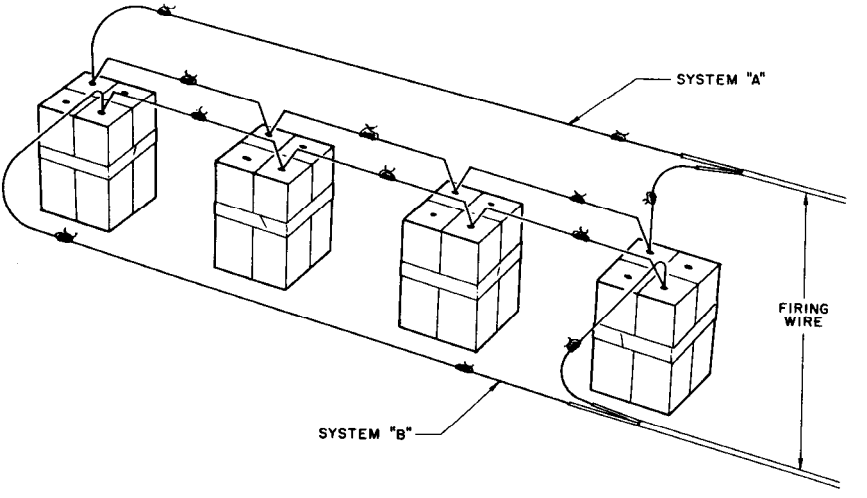


Figure 92. Electric dual firing system.

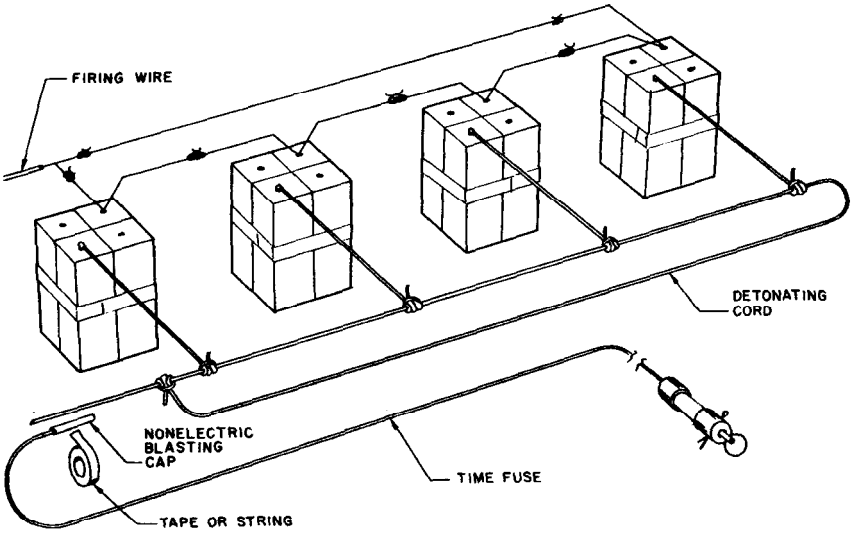


Figure 93. Combination dual firing system.

CHAPTER 3

CALCULATION AND PLACEMENT OF CHARGES

Section I. INTRODUCTION

76. Critical Factors in Demolitions

The critical factors in demolitions are the type of explosive used and the size, placement, and tamping of the charge.

a. Type of Explosive. Explosives used in military operations and their application to demolition projects are shown in table VIII.

Table VIII. Characteristics of Explosives

Name	Principal use	Smallest cap * required for detonation	Approx. velocity of detonation (meter/sec) (feet/sec)	Relative effectiveness as external charge (TNT=1.00)	Intensity of poisonous fumes	Water resistance
TNT	Main charge, booster charge, cutting and breaching charge, general and military use in forward areas	Special blasting cap	6,900 mps 23,000 fps	1.00	Dangerous	Excellent
Tetrytol			7,000 mps 23,000 fps	1.20	Dangerous	Excellent
Composition C 3			7,625 mps 25,018 fps	1.34	Dangerous	Good
Composition C 4			8,040 mps 26,379 fps	1.34	Slight	Excellent
Ammonium Nitrate	Cratering and ditching		3,400 mps 11,000 fps	0.42	Dangerous	Poor
Military Dynamite M1	Quarry and rock cuts		6,100 mps 20,000 fps	0.92	Dangerous	Good
Straight Dynamite (commercial) 40%	Land clearing, cratering quarrying, and general use in rear areas	No. 6 commercial cap	4,600 mps 15,000 fps	0.65	Dangerous	Good (if fired within 24 hours)
Straight Dynamite (commercial) 50%			5,500 mps 18,000 fps	0.79		
Straight Dynamite (commercial) 60%			5,800 mps 19,000 fps	0.83		
Ammonia Dynamite (commercial) 40%	Land clearing, cratering quarrying, and general use in rear areas	No. 6 commercial cap	2,700 mps 8,900 fps	0.41	Dangerous	Poor
Ammonia Dynamite (commercial) 50%			3,400 mps 11,000 fps	0.46		
Ammonia Dynamite (commercial) 60%			3,700 mps 12,000 fps	0.53		
Gelatin Dynamite (commercial) 40%	Land clearing, cratering quarrying, and general use in rear areas	No. 6 commercial cap	2,400 mps 7,900 fps	0.42	Slight	Good
Gelatin Dynamite (commercial) 50%			2,700 mps 8,900 fps	0.47		
Gelatin Dynamite (commercial) 60%			4,900 mps 16,000 fps	0.76		

Table VIII. Characteristics of Explosives—Continued

Name	Principal use	Smallest cap * required for detonation	Approx. velocity of detonation (meter/sec) (feet/sec)	Relative effectiveness as external charge (TNT=1.00)	Intensity of poisonous fumes	Water resistance
Ammonia Gelatin Dynamite (commercial) 40% 60%	Land clearing, cratering quarrying, and general use in rear areas	No. 6 commercial cap	4,900 mps 16,000 fps 5,700 mps 18,700 fps		Slight	Excellent
PETN	Detonating cord Blasting caps	Special blasting cap N/A	7,300 mps 24,000 fps	1.66	Slight	Good
TETRYL	Booster charge	Special blasting cap	7,100 mps 23,300 fps	1.25	Dangerous	Excellent
RDX	Base charge in blasting caps		8,350 mps 27,440 fps	1.50		
Composition B	Shaped charges	Special blasting cap	7,800 mps 25,600 fps	1.35	Dangerous	Excellent
Amatol 80/20	Bangalore torpedo	Special blasting cap	4,900 mps 16,000 fps	1.17	Dangerous	Poor
Black Powder	Time blasting fuze	N/A	400 mps 1,312 fps	0.55	Dangerous	Poor

* Electric or nonelectric

Abbreviations: fps — feet per second; mps — meters per second; N/A — not applicable; No. — number; sec. — second(s)

b. Size of Charge. The amount of explosive used in a demolition project is determined by formula calculation, and by means of a computing tape or tables. Formulas for computing specific charges—timber and steel cutting, breaching, and so on—are given in succeeding sections of this chapter. In the formulas (for example, $P = D^2$), the value of P is the amount of TNT (in pounds) required for external charges. If other explosives are used, the value of P must be substituted according to the strength of these other explosives in relation to TNT. The substitution is computed by dividing the P value (TNT) by the relative effectiveness factor for the explosive to be used. Steel and timber charges should be computed by formula when possible.

c. Tamping. The detonation of an explosive produces pressure in all directions. If the charge is not completely sealed in or confined or of the material surrounding the explosive is not equally strong on all sides, the explosive force breaks through the weakest spot and part of the destructive effect is lost. To retain as much of this explosive force as possible, material is packed around the charge. This material is called *tamping material or tamping*, and the process, *tamping*. On the other hand, an internal charge (one placed in the target to be destroyed) is confined by packing material in the borehole on top of the charge as is done in quarrying and cratering. This is called *stemming*. Explosive charges are generally tamped and stemmed as described below.

d. Charge Placement.

(1) Charges should be placed at the position that will provide maximum effectiveness. For cratering, they are placed in holes in the ground; for breaking or collapsing stone or concrete, they are properly located on the surface or in boreholes; for cutting standing timber they may be tied on the outside or placed in boreholes, whichever is the more practical.

(2) Charges are fastened to the target by

wire, adhesive compound, friction tape, or string; propped against the target by means of a wooden or metal frame made of scrap or other available materials; or placed in boreholes. Special accessories are issued for this purpose—adhesive compound, the rivet-punching powder-actuated driver, the earth auger, and pneumatic tools (para 29–41).

77. Types of Charges

a. Internal Charges. Internal charges are charges placed in boreholes in the target. These are confined by tightly packing sand, wet clay, or other material (stemming) into the opening. This is tamped and packed against the explosive to fill the hole all the way to the surface. In drill holes, tamping should not begin until the explosive is covered by at least one foot of stemming. Light materials are not acceptable, as they are apt to blow out of the borehole and cause incomplete destruction; neither are flammable materials like paper, sawdust, and sacking, which may ignite.

b. External Charges. These charges are placed on the surface of the target. They are tamped by covering them with tightly packed sand, clay, or other dense material. Tamping may be in sandbags or loose. For maximum effectiveness the thickness of the tamping should at least equal the breaching radius. Small breaching charges on horizontal surfaces are sometimes tamped by packing several inches of wet clay or mud around them. This process is called mudcapping.

Section II. TIMBER-CUTTING CHARGES

78. Size and Placement of Charge

For untamped external charges, block explosive (TNT, tetrytol, and Composition C3 and C4) is adequate, as it is easily tied or fastened in place and the charge size is calculated by formula based on its effectiveness in relation to that of TNT (relative effectiveness factor). For tamped internal charges in boreholes, dynamite is generally used, as it is the most convenient to place because of the size of the cartridge and is powerful enough because it is confined. It is impractical to attempt to cut all kinds of timber with charges of a size calculated from a single formula. There is too much variation in different kinds of timber from locality to locality. Accordingly, test shots must be made to determine the size of the charge to cut a specific type of timber. Formulas for the calculation of these shots are provided for untamped external charges, felling trees for an abatis, and for tamped internal charges. They are as follows:

a. Formula for Untamped External Charges. For cutting trees, piles, posts, beams, or other timber members with an untamped external charge, the following formula is used for the test shot for either round or rectangular members:

$$P = \frac{D^2}{40}$$

P = pounds of TNT required,
P = least diameter of the timber in inches or the least dimension of dressed timber, and
40 = constant

Adjustment for explosives other than TNT will be made using the relative effectiveness factor (table VIII) that pertains to the particular explosive being used. The amount of explosive required to cut a round timber 30 inches in diameter using an untamped external charge is determined as follows:

$$P = \frac{D^2}{40}$$

D = 30 inches

$$P = \frac{(30)^2}{40} = 22.5 \text{ pounds of TNT.}$$

b. Formula for Partially Cutting Trees to Create an Obstacle or Abatis. When cutting trees and leaving them attached to the stumps to create an obstacle, the formula $P = \frac{D^2}{50}$ is used to compute the amount of TNT required for the test shot. The result of the test shot

will determine the need for increasing or decreasing the amount of explosive required for subsequent shots

c. Formula For Tamped Internal Charges. Tamped internal cutting charges may be calculated by the following formula:

$$P = \frac{D^2}{250}$$

P = pounds of explosive required,
D = diameter or least dimension of dressed timber, in inches, and
250 = constant

Note. P = any explosive; relative effectiveness factor is not pertinent.

The amount of explosive required to cut a 15-inch diameter tree, using tamped internal charges, is determined as follows:

$$P = \frac{D^2}{250}$$

$$P = \frac{15^2}{250} = \frac{225}{250} = 0.90 \text{ or } 1 \text{ pound}$$

Note. See rounding off rule para 81*b*(4).

d. External Charge Placement. External charges are placed as close as possible to the surface of the timber regardless of the kind of cut desired (fig. 94). Frequently it is desirable to notch the tree to hold the explosive in place. If the tree or timber is not round and the direction of fall is of no concern, the explosive is placed on the widest face so that the cut will be through the least thickness. The tree will fall toward the side where the explosive is placed, unless influenced by lean or wind. To make the direction of fall certain a "kicker charge," a one-pound block of TNT, placed about two-thirds of the distance up the tree on the opposite side has proved excellent (fig. 94). Charges on rectangular or square dressed timber are placed as shown in figure 95.

e. Internal Charge Placement. These charges are placed in boreholds parallel to the greatest dimension of cross section and tightly tamped with moist clay or sand. If the charge is too large to be placed in one borehole, bore two side by side. On round timber, bore the two holes at approximately right angles to each other, but not to intersect (fig. 96). Both boreholes are tamped and the charges are fired simultaneously.

Figure 94. External timber-cutting charge.

79. Abatis

Charges for making fallen-tree obstacles are placed the same as those in paragraph 78, except that they are placed approximately 5 feet

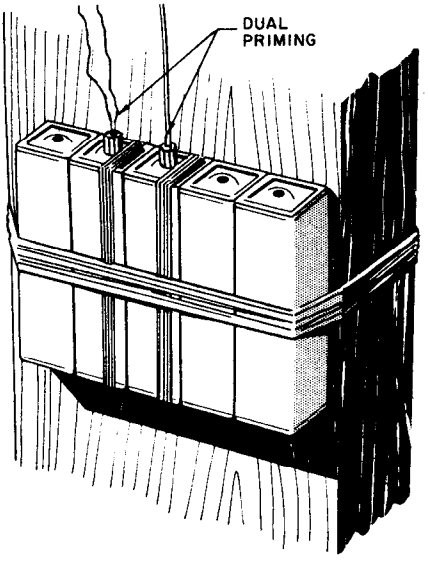


Figure 95. External cutting charge on rectangular timber.

above ground level. To make the obstacles more difficult to remove, they should be mined, boobytrapped, and covered by fire. To be effective these obstacles should be at least 75 meters in depth and the felled trees should extend at a 45° angle toward the enemy.

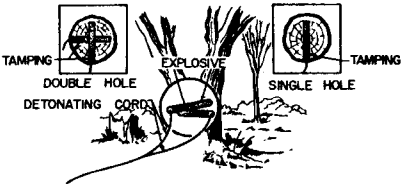


Figure 96. Internal timber-cutting charge.

Section III. STEEL-CUTTING CHARGES

80. Cutting Steel with Explosives

a. Principles of Detonation.

(1) When a high explosive detonates, the explosive changes violently from a solid into compressed gas at extremely high pressure. The rate of change is determined among other things by the type of explosive and the density, confinement, and the dimensions of the charge. Thus the detonation releases tremendous pressure in the form of a shock wave which, although it exists for only a few micro-seconds at any given point, may shatter and displace objects in its path as it proceeds from its point of origin. This shock wave is transmitted directly to any substance in contact with the charge, other characteristics being equal.

(2) A high explosive charge detonated in direct contact with a steel plate produces easily detectable destructive effects. An indentation or depression with an area about the size of the contact area of the explosive charge is made in the surface of the plate where the charge is exploded. A slab of metal—a spall or scab—is torn from the free surface of the plate directly opposite the explosive charge. This spalled metal is approximately the shape of the explosive charge, but

its area is usually greater than the contact area of the charge. The steel is split or fractured under the exploded charge along its entire length, and finally, a cross fracture is formed across the end of the charge away from the point of initiation. Variations in the dimensions of the charge, the shape of the steel member under attack, and the placement of the charge in relation to the steel member can alter the destructive effects described.

b. Significance of Charge Dimensions.

(1) The force of an explosion is proportional to the quantity and power of the explosive, but the destructive effect depends on the contact between the explosive and the target and on the manner that the explosive is directed at the target. For the maximum destructive effect against a steel target, an explosive charge with a configuration and dimensions optimum for the size and shape of the target must be detonated in intimate contact with the steel along the desired line of cut. As any air or water gap between the charge and the steel greatly reduces the cutting effect, close contact is essential. An optimum relation must exist between the area of the charge in contact with the target and charge thickness in order to transmit the greatest shock. If any given weight of explosive, calculated to cut a given target, is spread too thinly, there will be insufficient space for the detonation to attain full velocity before striking the target. The shock wave will tend to travel more nearly parallel than normal to the surface over much of the area; and the volume of the target will be excessive for the strength of the shock wave. On the other extreme, a thick charge with narrow contact area will transmit the shock wave over too little of the target with excessive lateral loss of energy. Test results have demonstrated conclusively that the optimum ratio of charge width to charge thickness is about 3:1 for contact steel cutting charges placed on structural members 3 inches thick or less. They have also demonstrated that the point of charge initiation has no significant effect on the shattering power of contact charges on steel. Successful explosive cutting of steel bars and structural steel beams with certain contact charges, however, requires charge initiation at specific points. These findings are applied in the discussion on steel-cutting formulas given below.

(2) Thus, in the preparation of steel cutting charges, the factors of type, size, and placement of the explosive are important for successful operations. The confinement or tamping of the charge is rarely practical or possible. Formulas for the computation of the size of the charge vary with the types of steel—structural, high carbon, and so forth. Placement, frequently harder to accomplish on steel structures than on others, is aided by the use of plastic explosive and the M118 special sheet explosive.

c. Explosive Used. Steel cutting charges are selected because of their cutting effect and adaptability to placement. Plastic explosive (C4) and sheet explosive M118 are the most desirable as they have high detonation velocity and other characteristics that give them great cutting power. C4 (M56A1) can be molded or cut to fit tightly into the grooves and angles of the target, particularly structural steel, chains, and steel cables; but the M112 block, also C4, is more adaptable because of its adhesive compound on one face, which fixes it more securely on the target. Sheet explosive, because of its width (3 in.), thickness (¼ in.), and adhesive, is more desirable for some steel targets than either the M5A1 or M112 demolition block. TNT, on the other hand, is adequate, generally available, and cast into blocks that may be readily assembled and fixed, but not molded to the target.

81. Size of Charge Determined by Type and Size of Steel

a. Types of Steel.

(1) *Structural.* Examples of this are I-beams, wide-flanged beams, channels, angle sections, structural tees, and steel plates used in building or bridge construction. These are the types of steel usually present in demolition projects. The formula in *b*(1), below, is applicable to structural steel, except for cutting slender structural bars (2 inches or less in diameter) where placement difficulties require the use of the formula in *b*(2)(*b*) below.

(2) *High-carbon.* This type of steel is used in the construction of metal-working dies and rolls. The formula in *b*(2)(*a*), below, is applicable.

(3) *Alloy.* Gears, shafts, tools, and plowshares generally are made of alloy steel. Chains and cables also are often made from alloy steel; some, however, are made of a high-carbon steel. The formula in *b*(2)(*a*), below, applies to high carbon or alloy steel.

(4) *Nickel-molybdenum steel and cast iron.* Cast iron, being very brittle, breaks easily, but nickel-molybdenum steel cannot be cut by demolition blocks. The jet from a shaped charge will penetrate it, but cutting will require multiple charges. Accordingly, nickel-molybdenum steel should be cut by some method other than explosives—acetylene or electric cutting tools, for example.

b. Calculation of Charges.

(1) *Formula for structural steel.* Charges to cut I-beams, builtup girders, steel plates, columns, and other structural steel sections are computed by formula as follows:

$$P = \frac{3}{8} A$$

P = pounds of TNT required,
A = cross-section area, in square inches, of the steel member to be cut, and

$$\frac{3}{8} = \text{constant}$$

(2) *Formula for other steels.*

(*a*) The formula below is recommended for the computation of cutting charges for high-carbon or alloy steel, such as that found in machinery.

$P = D^2$
P = pounds of TNT
D = diameter or thickness in inches of section to be cut.

(*b*) For round steel bars, such as concrete reinforcing rods, where the small size makes charge placement difficult or impossible and for chains, cables, strong forgings, steel rods, machine parts, and high-strength tools of a diameter of 2 inches or less use—

P = D
P = pounds of TNT
D = diameter in inches of section to be cut.

Such steel, however, may be cut by "rule of thumb:"

For round bars up to 1 inch in diameter, use 1 pound TNT.
For round bars over 1 inch up to 2 inches in diameter, use 2 pounds of TNT.

(3) *Railroad rail.* The size of railroad rail is usually expressed in terms of weight per yard. Rails over 80 pounds per yard (more than 5 inches in height) may be cut with 1 pound of TNT. For rails less than 80 pounds per yard (5 inches or less in height), ½ pound of TNT is adequate.

(4) *"Rounding-off" rule.* Charges calculated by formulas should be "rounded-off" to the next higher unit package of explosive. However, when a ½-pound charge is required, and only 2½-pound blocks are available, cut the blocks to proper size if feasible. For charges other than TNT, apply the

"rounding off" rule at completion of relative effectiveness factor calculations.

(5) *Problem: cutting steel* I-*beam.* Determine the amount of TNT required to cut the steel I-beam shown in figure 97. The solution is given in the figure.

(6) *Problem: explosives other than TNT.* Determine the amount of C4 explosive required to cut the steel I-beam in figure 97.

The amount of TNT $= 3\ \frac{27}{64}$

As C4 is 1.34 times as effective as TNT

$$P \text{ (of C4)} = \frac{\frac{219}{64}}{1.34} = 2.5 \text{ pounds}$$

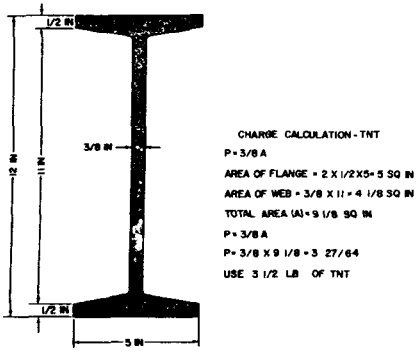

1/2 IN
3/8 IN
5 IN
CHARGE CALCULATION - TNT
P = 3/8 A
AREA OF FLANGE = 2 X 1/2 X 5 = 5 SQ IN
AREA OF WEB = 3/8 X 11 = 4 1/8 SQ IN
TOTAL AREA (A) = 9 1/8 SQ IN
P = 3/8 A
P = 3/8 X 9 1/8 = 3 27/64
USE 3 1/2 LB OF TNT

Figure 97. Calculation of charge of cut steel I *beam.*

(7) *Problem: cutting steel chain.* How much TNT is needed to cut the steel chain in figure 98? The solution is given in figure 98. Notice that the link is to be cut in two places (one cut on each side) to cause complete failure. If the explosive is long enough to bridge both sides of the link, or large enough to fit snugly between the two sides, use only one charge; but if it is not, use two separately-primed charges.

P = D
P = POUNDS OF TNT REQUIRED, AND
D = DIAMETER IN INCHES OF STEEL CHAIN TO BE CUT
D = 1 INCH

P = 1
P = 1 POUND OF TNT, IF BLOCK WILL BRIDGE LINK; IF NOT, USE TWO BLOCKS, ONE ON EACH SIDE OF LINK

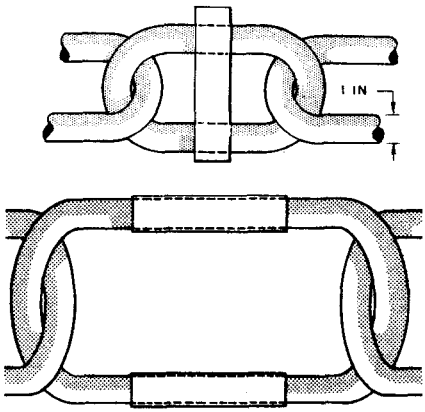


Figure 98. Calculation of charge to cut steel chain.

(8) *Use of the table in making calculations.* Table IX below, shows the correct weight of TNT necessary to cut steel sections of various dimensions calculated from the formula $P = \frac{3}{8}$

A. In using this table:

(*a*) Measure separately the rectangular sections of members.

(*b*) Find the corresponding charge for each section by using the table.

(*c*) Total the charges for the sections.

(*d*) Use the next larger given dimension if dimensions of sections do not appear in the table.

Caution: Never use less than the calculated amount.

Table IX. TNT Needed to Cut Steel Sections

Average thickness of section in inches	Pounds of explosive * for rectangular steel sections of given dimensions																
	Height of section in inches																
	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24
¼	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.3
⅜	0.3	0.5	0.6	0.7	0.9	1.1	1.2	1.3	1.4	1.6	1.7	2.0	2.3	2.6	2.8	3.1	3.4
½	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.7	3.0	3.4	3.8	4.2	4.5
⅝	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	2.4	2.7	2.9	3.3	3.8	4.3	4.7	5.2	5.7
¾	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.1	3.4	4.0	4.5	5.1	5.7	6.3	6.8
⅞	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.0	3.3	3.7	4.0	4.6	5.3	6.0	6.6	7.3	7.9
1	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	5.3	6.0	6.8	7.5	8.3	9.0

* TNT

To use:

1. Measure rectangular sections of *members* separately.
2. Using table, find charge for each section.
3. Add charges for sections to find total charge.
4. If dimensions of sections do not appear on table, use the next larger dimension.

e. Problem. The problem in figure 97 may be solved as follows:

Charge for flanges:
width = 5 inches
thickness = ½ inch
Charge from table =
1.0 pounds

Charge for web:
height = 11 inches
thickness = ⅜ inch
Charge from table =
1.6 pounds

Total charge: 2 flanges = 2 x 1.0 = 2.0 pounds
web = 1 x 1.6 = 1.6 pounds
Use 4 pounds of TNT. 3.6 pounds

82. Charge Placement

a. Steel Sections. The size and type of a steel section determine the placement of the explosive charge. Some elongated sections may be cut by placing the explosive on one side of the section completely along the proposed line of rupture. In some steel trusses in which the individual members are fabricated from two or more primary sections, such as angle irons or bars separated by spacer washers or gusset plates, the charge has to be cut with the opposing portions of the charge slightly offset to produce a shearing action (para 83*d*(4)). Heavier H-beams, wide flange beams, and columns may also require auxiliary charges placed on the outside of the flanges. Care must be taken to insure that opposing charges are never directly opposite each other, otherwise they tend to neutralize the explosive effect.

b. Rods, Chains, and Cables. Block explosive, often difficult to emplace, is not recommended for cutting steel rods, chains, and cables if plastic explosive is available.

c. Steel Members and Railroad Rails. Charge placement for cutting these is found in figures 99 and 140.

d. Built-up Members. Built-up members frequently have an irregular shape, which makes it difficult to obtain a close contact between the explosive charge and all of the surface. If it is impractical to distribute the charge properly to obtain close contact, the amount of explosive should be increased.

e. Irregular Steel Shapes. Composition C4 (M2A1 block) is a good explosive for cutting irregular steel shapes because it is easily molded or pressed into place to give maximum contact. A light coating of adhesive compound applied to the steel surface will help hold the explosive on the target. The M112 block, also C4, has an adhesive coating on one side and the M118 sheet explosive has a similar coating, which makes placement easier (para 80*c*).

f. Securing Explosives in Place. All ex-

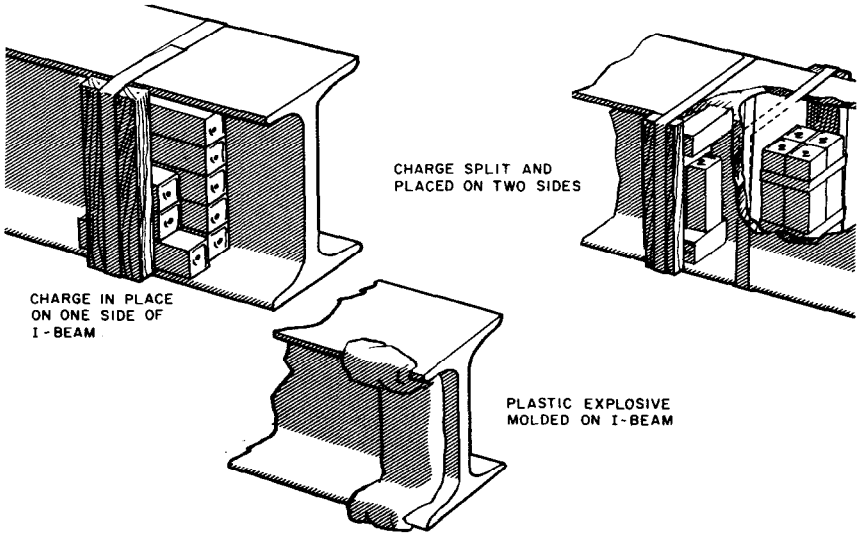


Figure 99. Placement of charges on steel members.

plosives except moldable or adhesive types must be tied, taped, or wedged in place unless they rest on horizontal surfaces and are not in danger of being jarred out of place.

g. Precautions. In cutting steel, the charge should be placed on the same side as the firing party, as explosive charges throw steel fragments (missiles) long distance at high velocities.

83. Special Steel Cutting Techniques

a. Use of Special Techniques. Three types of steel cutting charges are available for use, the saddle charge, diamond charge, and ribbon charge. They are prepared in advance for transportation to the site by wrapping them in aluminum foil or heavy paper. Not more than one thickness of the wrapper should be between the explosive and the target.

b. Saddle Charge. This charge is used on solid cylindrical mild steel targets up to 8 inches in diameter. Detonation is initiated at the apex of the long axis (fig. 100).

(1) *Size of charge.*

(*a*) Thickness of charge = 1/3 of the thickness of M5A1 block of plastic explosive (2/3 inch) for targets up to 19 inches in circumference (6 inches in diameter); and ½ the thickness of M5A1 block of plastic explosive (1 inch) for targets from 19 to 25 inches in circumference (over 6 to 8 inches in diameter).

(*b*) Base of charge = ½ circumference of target.

(*c*) Long axis of charge = circumference of target.

(2) *Example.* Determine the dimensions of a charge for cutting a shaft 18 inches in circumference (may be measured by a length of string).

(*a*) Thickness = 1/3 thickness of M5A1 block of plastic explosive (2/3 inch).

(*b*) Base = ½ x 18 = 9 inches

(*c*) Long axis = 18 inches.

Charge is 9 inches at base, 18 inches at long axis, and 2/3 inch thick.

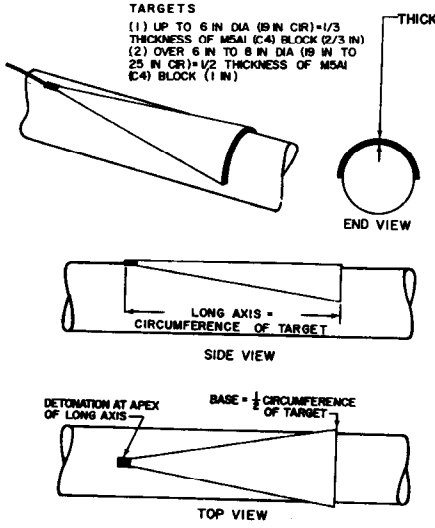

TARGETS
(1) UP TO 6 IN DIA (18 IN CIR)=1/3 THICKNESS OF M5A1 (C4) BLOCK (2/3 IN)
(2) OVER 6 IN TO 8 IN DIA (19 IN TO 25 IN CIR)=1/2 THICKNESS OF M5A1 (C4) BLOCK (1 IN)
THICKNESS
END VIEW
LONG AXIS = CIRCUMFERENCE OF TARGET
SIDE VIEW
DETONATION AT APEX OF LONG AXIS
BASE = 1/2 CIRCUMFERENCE OF TARGET
TOP VIEW

Figure 100. Saddle charge.

Note. Steel alloy and mild steel targets over 25 inches in circumference (over 8 inches in diameter) require the diamond charge (*c* below).

(3) *Placement.* The long axis of the saddle should be parallel with the long axis of the target. Detonation of the charge is by the placement of a military electric or nonelectric blasting cap at the apex of the long axis.

c. Diamond Charge. This is used on high carbon steel or steel alloy targets (fig. 101). It is shaped like a diamond.

(1) *Size of charge.* The size of the charge depends on the dimensions of the target.

(*a*) Long axis of charge = circumference of the target.

(*b*) Short axis of charge = ½ the circumference of the target.

(*c*) Thickness of charge = 1/3 the thickness of M5A1 block of plastic explosive (2/3 inch).

(2) *Example.* Determine the size of a charge for cutting a steel alloy shaft 15 inches in circumference.

(*a*) Long axis = 15 inches.

(*b*) Short axis = ½ x 15 = 7½ inches.

(*c*) Thickness = 1/3 the thickness of M5A1 block of plastic explosive or 2/3 inch. Charge is 15 inches at long axis, 7½ at short axis, and 2/3 inch thick.

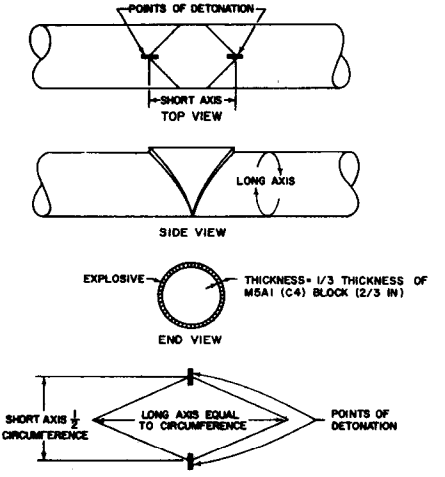


Figure 101. Diamond charge.

(3) *Placement.* Wrap the explosive completely around the target so that the ends of the long axis touch. Detonate the charges simultaneously from both short axis ends. This may be done by priming with two pieces of detonating cord of the *same length* with nonelectric blasting caps crimped to the ends, or two electric blasting caps connected in series.

d. Ribbon Charge. This charge, if properly calculated and placed, cuts steel with considerably less explosive than standard charges. It is effective on noncircular steel targets up to 2 inches thick (fig. 102).

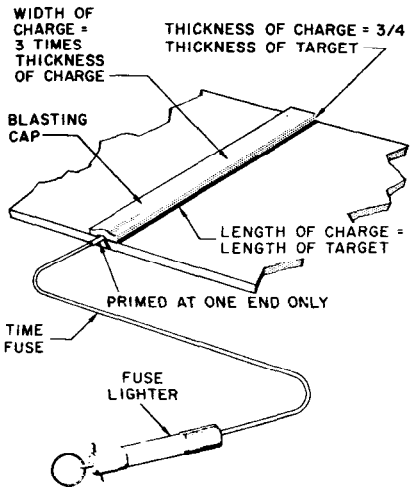

WIDTH OF CHARGE = 3 TIMES THICKNESS OF CHARGE
THICKNESS OF CHARGE = 3/4 THICKNESS OF TARGET
BLASTING CAP
LENGTH OF CHARGE = LENGTH OF TARGET
PRIMED AT ONE END ONLY
TIME FUSE
FUSE LIGHTER

Figure 102. Ribbon charge.

(1) *Calculation.* The effectiveness of the blast depends on the width and thickness of the explosive.

(*a*) Thickness of charge = ¾ thickness of the target.

(*b*) Width of charge = 3 x the thickness of the charge.

(*c*) Length of charge = length of the cut.

Note. Charge should never be less than ½-inch thick.

(2) *Example.* Determine the thickness and width of a ribbon charge for cutting a steel plate 1 inch thick.

(*a*) Thickness = ¾ thickness of target 1 x ¾ = ¾ inch.

(*b*) Width = 3 x thickness of the charge 3 x ¾ = 2¼ inches. Charge is ¾ inches thick and 2¼ inches wide.

(3) *Detonation.* The ribbon charge is detonated from one end only. It may be necessary where the calculated thickness is small to "build up" the detonating end with extra explosive. Either the electric or nonelectric cap is satisfactory. The charge should extend slightly over the target at each end to insure a complete cut. The steel member will be ruptured at approximately the linear axis of the ribbon.

(4) *Use on structural steel sections.* The ribbon charge (computed by formula given in (2), above) has a proven application to cutting structural steel sections (fig. 103). On wide-flanged beams of less than 2 inches of steel thickness, a C-shaped charge is placed on one side to cut the web and half of the top and bottom flanges. The other sides of these flanges are cut by two offset ribbon charges, placed so that one edge is opposite the center of the C-shaped charge as shown in A, figure 103. For beams with steel

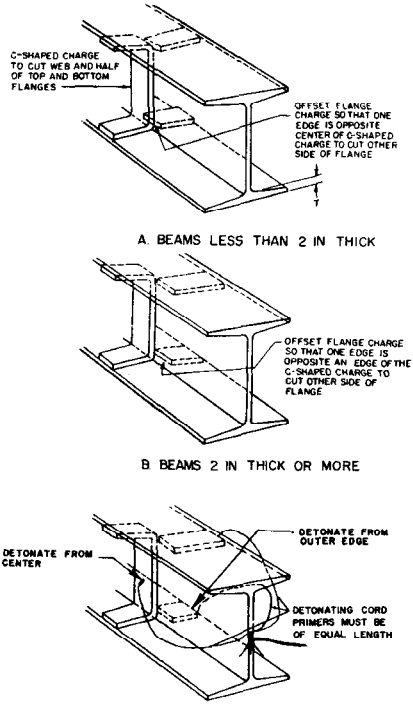

C-SHAPED CHARGE TO CUT WEB AND HALF OF TOP AND BOTTOM FLANGES
OFFSET FLANGE CHARGE SO THAT ONE EDGE IS OPPOSITE CENTER OF C-SHAPED CHARGE TO CUT OTHER SIDE OF FLANGE
A. BEAMS LESS THAN 2 IN THICK
OFFSET FLANGE CHARGE SO THAT ONE EDGE IS OPPOSITE AN EDGE OF THE C-SHAPED CHARGE TO CUT OTHER SIDE OF FLANGE
B. BEAMS 2 IN THICK OR MORE
DETONATE FROM CENTER
DETONATE FROM OUTER EDGE
DETONATING CORD PRIMERS MUST BE OF EQUAL LENGTH
C. PRIMING

Figure 103. Placement of ribbon charges on structural steel sections.

thickness of 2 inches and over, the offset charges are placed opposite an edge of the C-shaped charge as shown in B, figure 103. For optimum results, the charges must be primed with three equal lengths of detonating cord with blasting caps attached and placed in the charges as in C, figure 103 to provide simultaneous detonation. The three charges are initiated by an electric or nonelectric system.

Note. It is possible that on heavily-loaded beams the C-shaped ribbon charge placed on one side (fig. 103) will be adequate. The uncut sides of the flanges may fail without the use of offset charges because of the weight. This technique, however, must be used with discretion to eliminate possibility of failure.

Section IV. PRESSURE CHARGES

84. Size of Charge

The pressure charge is used primarily for the demolition of simple span reinforced concrete T-beam bridges and cantilever bridges.

a. Formula for Tamped Pressure Charges. The amount of TNT required for a tamped pressure charge is calculated by the formula below. If explosive other than TNT is used, the calculated value must be adjusted.

$P = 3H^2T$

P = pounds of TNT required for each beam (stringer).

H = height of beam (including thickness of roadway) in feet

T = thickness of beam in feet

However, the values of H and T, if not whole numbers should have the fraction expressed in ¼-foot increments by rounding off to the next higher ¼-foot dimension. H and T are never considered less than 1 foot.

b. Formula for Untamped Pressure Charges. The value calculated for P by the above formula is increased by one-third if the pressure charge is not tamped to a minimum of 10 inches.

c. Problem: Pressure Charges. Determine the amount of TNT required to destroy the bridge span shown in figure 104. The solution to this problem is found in the figure. Notice that the quantity of explosive given by the formula refers to the charge for each beam. Thus four of these 41-pound charges should be placed as shown in the figure.

d. Use of Table in Making Calculations. Table X, gives the various weights of TNT required to provide suitable tamped pressure charges. The weights of TNT in the table were calculated from the formula $P = 3H^2T$ and the values were rounded off to the next highest pound. To use the table proceed as follows:

(1) Select the appropriate value in the "Height of beam" column.
(2) Read the weight of the TNT from the column corresponding to the thickness of the beam.

e. Example. The height of the beam in the problem in figure 104 is 34 inches and the thickness is 17 inches. In table X (36-inch height and 18-inch thickness columns), the weight of TNT for the tamped pressure charge is indicated as 41 pounds. For untamped charges the weight values given in the table are increased by one-third.

85. Charge Placement and Tamping

a. Placement. The correct amount of explosive is placed on the roadway over the centerline of each stringer (fig. 104) and alined midway between the ends of the span. If a curb or side rail prevents placing the charge directly above the outside stringer, it is placed against the curb or side rail. This does not require an increase in the size of the explosive charge.

b. Tamping. Pressure charges should be tamped whenever possible. Effective tamping requires a minimum of 10 inches of material. All charges are primed to fire simultaneously.

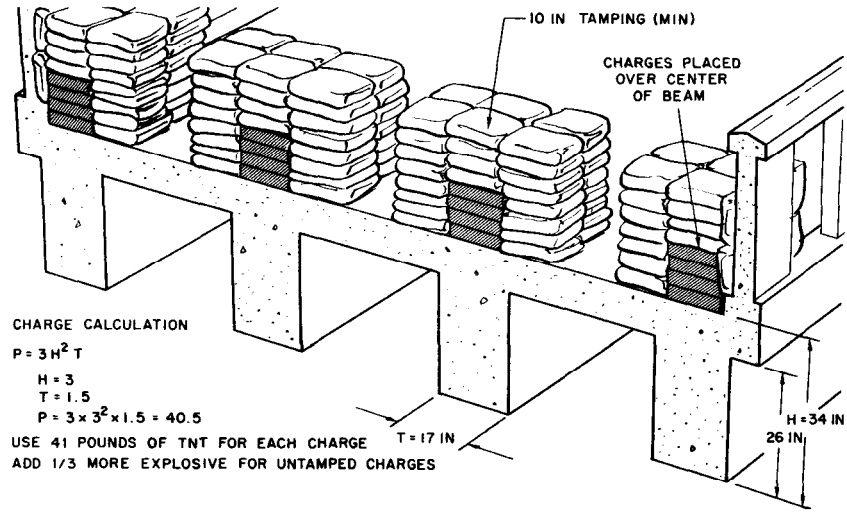

10 IN TAMPING (MIN)
CHARGES PLACED OVER CENTER OF BEAM
CHARGE CALCULATION
P = 3 H² T
H = 3
T = 1.5
P = 3 x 3² x 1.5 = 40.5
USE 41 POUNDS OF TNT FOR EACH CHARGE
ADD 1/3 MORE EXPLOSIVE FOR UNTAMPED CHARGES
T = 17 IN
H = 34 IN
26 IN

Figure 104. Calculation and placement of pressure charges.

Table X. TNT Required for Tamped Pressure Charges

Pounds of explosive for each beam (tamped charges)* (TNT)

Height of beam in feet	Thickness of beam in feet								
	1 (12 in.)	1¼ (15 in.)	1½ (18 in.)	1¾ (21 in.)	2 (24 in.)	2¼ (27 in.)	2½ (30 in.)	2¾ (33 in.)	3 (36 in.)
1 (12 in.)	3	-----	-----	-----	-----	-----	-----	-----	-----
1 ¼ (15 in.)	5	6	-----	-----	-----	-----	-----	-----	-----
1 ½ (18 in.)	7	9	11	-----	-----	-----	-----	-----	-----
1 ¾ (21 in.)	10	12	14	16	-----	-----	-----	-----	-----
2 (24 in.)	12	15	18	21	24	-----	-----	-----	-----
2 ¼ (27 in.)	16	19	23	27	31	35	-----	-----	-----
2 ½ (30 in.)	19	24	29	33	38	43	47	-----	-----
2 ¾ (33 in.)	23	29	34	40	46	51	57	63	-----
3 (36 in.)	27	34	41	48	54	61	68	75	81
3 ¼ (39 in.)	32	40	48	56	64	72	80	88	95
3 ½ (42 in.)	37	46	56	65	73	83	92	101	111
3 ¾ (45 in.)	43	53	64	74	85	95	106	116	127
4 (48 in.)	48	60	72	84	96	108	120	132	144
4 ¼ (51 in.)	55	68	82	95	109	122	136	149	163
4 ½ (54 in.)	61	76	92	107	122	137	152	167	183
4 ¾ (57 in.)	68	85	102	119	136	153	170	187	203
5 (60 in.)	75	94	113	132	150	169	188	207	225

* Increase weights by 1/3 for untamped charges. (Minimum tamping required is 10 inches.)

SECTION V. BREACHING CHARGES

86. Critical Factors and Computation

Breaching charges are applied chiefly to the destruction of concrete slab bridges, bridge piers, bridge abutments, and permanent field fortifications. The size, placement, and tamping or confinement of the breaching charge are critical factors — the size and confinement of the explosive being relatively more important because of strength and bulk of the materials to be breached. High explosive breaching charges, detonated in or against concrete and rock, must produce a shock so intense that it breaks or shatters the material. The metal reinforcing bars often found in concrete are not always cut by breaching charges. If it is necessary to remove the reinforcement, the steel cutting formula (para (*b*) 81*b* (2) (*b*)) is used.

a. Calculation Formula. The size of a charge required to breach concrete, masonry, rock, or similar material is calculated by the formula below. By proper adjustment of the P-value, the charge size for any other explosive may be readily determined.

$P = R^3KC$

P = pounds of TNT required

R = breaching radius, in feet (*b* below)

K = material factor, given in table XI, which reflects the strength and hardness of the material to be demolished (*c* below)

C = a tamping factor, given in figure 105 which depends on the location and tamping of the charge (*d* below)

Note. For breaching walls 1 foot thick or less, increase the total calculated charge by 50 percent. Add 10 percent for charges under 50 pounds.

b. Breaching Radius R. The breaching radius

Table XI. Value of K (Material Factor) for Breaching Charges

Material	Breaching radius	K
Ordinary earth	All values	0.05
Poor masonry, shale and hardpan; good timber and earth construction	All values	0.23
Good masonry, ordinary concrete, rock	Less than 3 feet	0.35
	3 feet to less than 5 feet	.28
	5 feet to less than 7 feet	.25
	7 feet or more	.23
Dense concrete, first-class masonry	Less than 3 feet	0.45
	3 feet to less than 5 feet	.38
	5 feet to less than 7 feet	.33
	7 feet or more	.28
Reinforced concrete (concrete only; will not cut steel reinforcing)	Less than 3 feet	0.70
	3 feet to less than 5 feet	.55
	5 feet to less than 7 feet	.50
	7 feet or more	.43

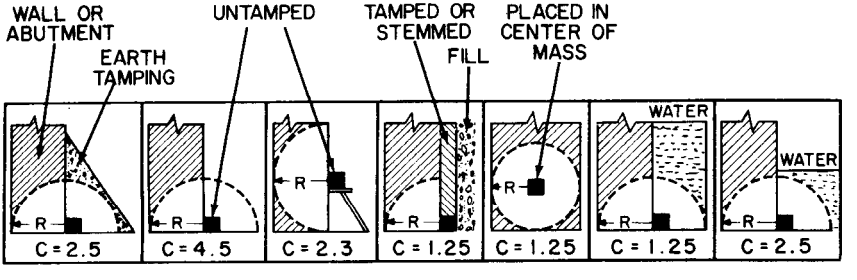
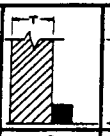


Figure 105. Value of C (tamping factor) for breaching charges.

R is the distance in feet from an explosive in which all material is displaced or destroyed. The breaching radius for external charges is the thickness of the mass to be breached. The breaching radius for internal charges is one-half the thickness of the mass to be breached if

THICKNESS OF CONCRETE IN FEET	METHODS OF PLACEMENT							DISTANCE BETWEEN CHARGES IN FEET	
	TNT (LB)						ANY	INTERNAL	EXTERNAL
									
COLUMN	1	2	3	4	5	6	7	8	9
2	16	28	15	8	8	16	1	2	4
2½	31	55	28	16	16	31	2	2½	5
3	41	67	38	21	21	41	4	3	6
3½	59	107	55	33	33	59	6	3½	7
4	88	159	81	49	49	88	8	4	8
4½	126	226	116	63	63	126	11	4½	9
5	157	282	144	79	79	157	16	5	10
5½	208	375	192	104	104	208	20	5½	11
6	270	486	249	135	135	270	21	6	12
6½	344	618	316	172	172	344	26	6½	13
7	369	664	340	185	185	369	33	7	14
7½	454	817	418	227	227	454	40	7½	15
8	551	991	507	276	276	551	49	8	16

Notes:

1. 10% has been added to the table for charges less than 50 lbs.
2. For best results place charge in shape of a square.
3. For thickness of concrete of 4 ft or less use charge thickness of 2 in (one block thick); over 4 ft thick, use charge thickness of 4 in (one haversack of tetrytol or plastic (M5A1)).

To use table:

1. Measure thickness of concrete.
2. Decide how you will place the charge against the concrete. Compare your method of placement with the diagrams at the top of the page. If there is any question as to which column to use, always use the column that will give you the greater amount of TNT.
3. For calculating explosives other than TNT, use relative effectiveness factor (Table VIII).

Figure 106. Breaching charge calculations.

the charge is placed midway into the mass. If holes are drilled less than halfway into the mass, the breaching radius becomes the longer distance from end of the hole to the outside of the mass. For example, if a 4-foot wall is to be breached by an internal charge placed 1 foot into the mass, the breaching radius is 3 feet. If it is to be breached by a centered internal charge, the breaching radius is 2 feet. The breaching radius is 4 feet if an external charge is used. Values of R are rounded off to the next highest ½-foot.

c. Material Factor K. K is the factor that reflects the strength and hardness of the material to be breached. Table XI gives values for the factor K for various types of material. When it is not known whether or not concrete is reinforced, it is assumed to be reinforced.

d. Tamping Factor C. The value of tamping factor C depends on the location and the tamping of the charge. Figure 105 shows typical methods for placing charges and gives values of C to be used in the breaching formula with both tamped and untamped charges. In selecting a value of C from figure 105, a charge tamped with a solid material such as sand or earth is not considered fully tamped unless it is covered to a depth equal to the breaching radius.

e. Use of Figure in Making Calculations. Figure 106 gives the weight of TNT required to breach reinforced and dense concrete targets. The weights of TNT in the table were calculated from the formula $P = R^3KC$ and the values were rounded off to the next highest pound.

f. Example. Using figure 106, calculate the amount of TNT required to breach a reinforced concrete wall 7 feet in thickness with an untamped charge placed at a distance R above the ground. From the figure (7 foot thickness and untamped charges placed at a distance R above the ground columns) the required weight of TNT is 340 pounds.

87. Placement and Number of Charges

a. Positions. In the demolition of piers and walls, the positions for the placement of explosive charges are rather limited. Unless a demolition chamber is available, the charge (or charges) may be placed against one face of the target either at ground level, somewhat above ground level, or beneath the surface. A charge placed above ground level is more effective than one placed directly on the ground. When several charges are required to destroy a pier, slab, or wall and elevated charges are desired, they are distributed equally at no less than 1 breaching radius high from the base of the object to be demolished. In this manner, the best use is obtained from the shock waves of the blast. All charges are thoroughly tamped with damp soil or filled sandbags if time permits. (Tamping must equal the breaching radius.) For piers, slabs, or walls partially submerged in water, charges are placed below the waterline. If underwater demolition is essential, the tamping factor for the placement of tamped charges with earth is used.

b. Number of Charges. The number of charges required for demolishing a pier, slab, or wall is determined by the formula:

$$N = \frac{W}{2R}$$

N = number of charges
W = width of pier, slab, or wall, in feet
R = breaching radius in feet (para 86*b*)

If the calculated value of N has a fraction less than ½, the fraction is disregarded, but if the calculated value of N has a fraction of ½ or more, the value is "rounded off" to the next higher whole number. An exception to this general rule is in calculated N-value between 1 and 2, in which a fraction less than ¼ is disregarded, but a fraction of ¼ or more is rounded off to the next higher whole number, or 2.

Section VI. CRATERING AND DITCHING CHARGES

88. Critical Factors

a. Explosive. A special cratering charge, ammonium nitrate, issued in a waterproof metal container, is used. When the ammonium nitrate charge is not available, other explosives may be substituted.

b. Size and Placement of Charge.

(1) *Basic factors.* In deliberate cratering,

holes are bored to specific depths and spaced according to computation by formula. Deliberate craters are a minimum of 8 feet deep. In hasty cratering, holes are more shallow, contain less explosive, and are spaced on 5-foot centers. The crater depth is 1½ times the depth of the borehole. In ditching, test shots are made and the diameter and depth are increased as required. The size of the cratering charge is determined as described in paragraphs 89 and 90.

(2) *Breaching hard-surfaced pavements for cratering charges.* Hard-surfaced pavement of roads and airfields is breached so that holes may be dug for cratering charges. This is done effectively by exploding tamped charges on the pavement surface. A 1-pound charge of explosive is used for each 2 inches of pavement thickness. It is tamped with material twice as thick as the pavement. The pavement may also be breached by charges placed in boreholes drilled or blasted through it. (A shaped charge readily blasts a small-diameter borehole through the pavement and into the subgrade). Concrete should not be breached at an expansion joint, because the concrete will shatter irregularly. After breaching, holes may be made by use of the earth rod kit (para 41*c*) and widened by the detonating cord wick (para 98*b*). Also an M2A3 shaped charge (fig. 8) detonated 30 inches above any kind of soil will produce a borehole deep enough to accept a cratering charge (table XII). But since these shaped-charge boreholes are usually tapered in diameter, they should be enlarged by means of a posthole digger, detonating cord wick, or other device.

c. Confinement of Charge. Charges at cratering sites and antitank ditching sites are placed in boreholes and properly stemmed. Those at culvert sites are tamped with sandbags.

Table XII. Size of Boreholes Made by Shaped Charges

				M3 shaped charge	M2A3 shaped charge
1	Reinforced concrete	Maximum wall thickness that can be perforated		60 in	36 in
2		Depth of penetration in thick walls		60 in	30 in
3		Diameter of hole (in)	Entrance	5 in	3½ in
4			Average	3½ in	2¾ in
5			Minimum	2 in	2 in
6		Depth of hole with second charge placed over first hole		84 in	45 in
7	Armor plate	Perforation		At least 20 in	12 in
8		Average diameter of hole		2½ in	1½ in
9	Permafrost	Depth of hole with 50-in standoff		72 in	N/A
10		Depth with 30-in standoff		N/A	72 in
11		Depth with 42-in standoff		N/A	60 in
12		Diameter of hole with average (30-in) standoff		N/A	6 in to 1½ in
13		Diameter of hole with 50-in standoff		8 in to 5 in	N/A
14		Diameter of hole with normal standoff		*26–30 in to 7 in	26–30 in to 4 in
15	Ice	Depth with average (42-in) standoff		12 ft.	7 ft
16		Diameter with average (42-in) standoff		6 in	3½ in

* Boreholes made by shaped charges are cone-shaped. The diameters shown in this table are top and bottom measurements.

89. Deliberate Road Crater

A deliberate road crater may be made in all materials except loose sand, regardless of the type of road surface. The method shown in figure 107 produces a clean V-shaped crater a minimum of 8 feet deep and 25 feet wide extending about 8 feet beyond each end charge. The method of placing charges is as follows:

a. Bore the holes 5 feet apart, center-to-center, in line across the roadway. The end holes are 7 feet deep and the others are alternately 5 feet and 7 feet deep. The formula for the computation of the number of holes is:

$$N = \frac{L-16}{5} + 1$$

L = length of crater in feet measured across roadway

Any fractional number of holes is rounded off to the next highest number. If a hole is too small to accept the cratering charge, enlarge it by use of the detonating cord wick (para 98*b*).

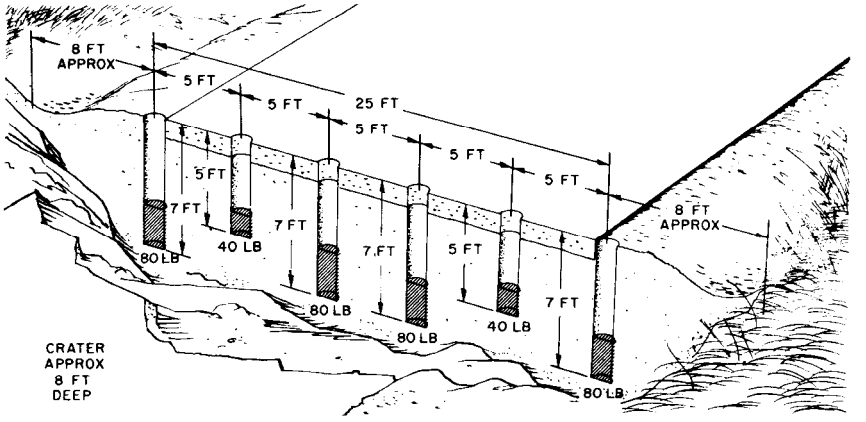


Figure 107. Charge placement for deliberate road crater.

b. Place 80 pounds of explosive in the 7-foot holes and 40 pounds of explosive in the 5-foot holes. Two 5-foot holes must not be made next to each other. If they are so calculated, one of them must be a 7-foot hole. The resulting two adjacent 7-foot holes may be placed anywhere along the line.

c. Prime all charges and connect them to fire simultaneously. A dual firing system should be used.

d. Place a 1-pound primer in each hole on top of the can for dual priming, if the standard cratering charge is used.

e. Stem all boreholes with suitable material.

90. Hasty Road Crater

Although a hasty road crater takes less time and less explosive for construction than a deliberate road crater, it is less effective because of its depth and shape. It does, however, make an excellent barrier for vehicles and small tanks (fig. 108). The method described below forms a crater about 1½ times deeper and 5 times wider than the depth of the boreholes and extends about 8 feet beyond each end charge. The sides have a slope of 30° to 60° depending on the soil. Craters formed by boreholes less than 4 feet deep and loaded with charges less than 40 pounds are ineffective against tanks. The following hasty cratering method has proved satisfactory:

a. Dig all boreholes to the same depth. This may vary from 2½ to 5 feet, depending upon the size of the crater needed. Space the holes 5 feet apart center-to-center across the road.

b. Load the boreholes with 10 pounds of explosive per foot of depth.

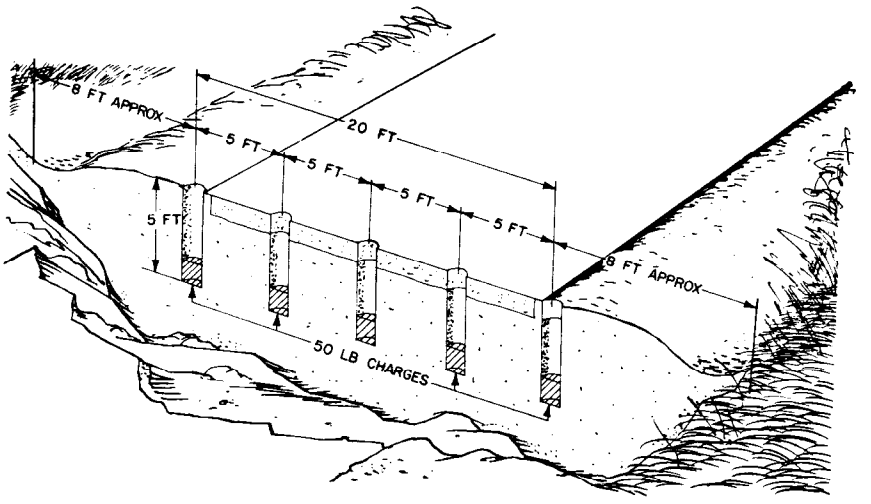


Figure 108. Charge placement for hasty road crater.

c. Prime the charges as for deliberate cratering.

d. Stem all holes with suitable material.

91. Special Cratering Methods

a. Relieved Face Cratering Method. This demolition technique produces a trapezoidal-shaped crater with unequal side slopes. The side nearest the enemy slopes at about 25° from the road surface to the bottom while that on the opposite or friendly side is about 30° to 40° steeper. The exact shape, however, depends on the type of soil found in the area of operations. In compact soil, such as clay, the relieved face cratering method will provide an obstacle shaped as shown in 1, figure 109. The procedure is as follows:

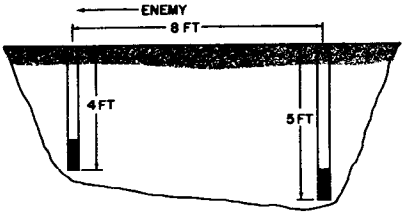
(1) Drill two rows of boreholes 8 feet apart, spacing the boreholes on 7-foot centers. On any road, the row on the friendly side will contain four boreholes. Stagger the boreholes in the row on the enemy side in relationship to the other row, as shown in 2, figure 109. This row will usually contain three boreholes or always one less than the other row (2, fig. 109).

(2) Make the boreholes on the friendly side 5 feet deep and load with 40 pounds of explosive, and those on the enemy side 4 feet deep and load with 30 pounds of explosive.

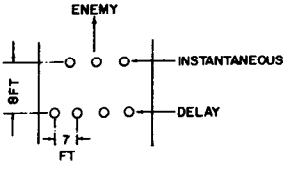
(3) Prime the charges in each row separately for simultaneous detonation. There should be a delay of detonation of ½ to 1½ seconds between rows, the row on the enemy side being detonated first. Best results will be obtained if the charges on the friendly side are fired while the earth moved in the first row is still in the air. Standard delay caps may be used for delay detonation.

(4) Acceptable results may be obtained by firing both rows simultaneously, if adequate means and sufficient time for delay firing are not available.

Note. While the procedure in (1), above, specifies four boreholes on the friendly side and three boreholes on the enemy side, more boreholes may be made if needed to crater



1. RELIEVED FACE CRATERING CHARGE



2. BOREHOLE PATTERN

Figure 109. Relieved face cratering.

wider roads or to make larger craters. They should be located and staggered, however, in the same manner as states in (1) above. To prevent misfires from the shock and blast of the row of charges on the enemy side (detonated first), the detonating cord mains and branch lines of the row on the friendly side (detonated last) should be protected by a covering of 6 to 8 inches of earth.

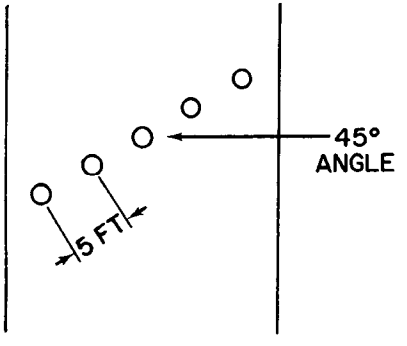


Figure 110. Angled cratering method.

b. Angled Cratering Method. This method is useful against tanks traveling in defiles or road cuts where they must approach the crater straightaway. A line of boreholes is blasted or drilled across a roadway at about a 45° angle, and charged as in figure 110. Because of the unevenness of the side slopes, tanks attempting to traverse an angled crater are usually halted effectively.

c. Standoff Distance. The standoff distance for making the boreholes on unpaved roads with M2A3 shaped charges should be 20 to 30 inches. For paved roads, the standoff distance should be about 36 inches. As the standoff distance is decreased, the depth of the open hole is decreased while the diameter is increased. In any case, test hole should be made to ascertain the optimum standoff distance.

d. Blasting Permafrost.

(1) *Number of boreholes and size of charge.* In permafrost, blasting requires about 1½ to 2 times the number of boreholes and larger charges than those calculated by standard formulas for moderate climates. Frozen soil, when blasted, breaks into large clods 12 to 18 inches thick and 6 to 8 feet in diameter. As the charge has insufficient force to blow these clods clear of the hole, they fall back into it when the blast subsides. Tests to determine the number of boreholes needed should be made before extensive blasting is attempted. In some cases, permafrost may be as difficult to blast as solid rock.

(2) *Methods of making boreholes.* Boreholes are made by three methods—standard drilling equipment, steam point drilling equipment, and shaped charges. Standard drill equipment has one serious defect—the air holes in the drill bits freeze and there is no known method of avoiding it. Steam point drilling is satisfactory in sand, silt, or clay, but not in gravel. Charges must placed immediately upon withdrawal of the steam point, otherwise the area

around the hole thaws and plugs it. Shaped charges also are satisfactory for producing boreholes, especially for cratering. Table XII shows the size of boreholes in permafrost and ice made by M3 and M2A3 shaped charges.

(3) *Explosives.* A low velocity explosive like ammonium nitrate, satisfactory for use in arctic temperatures, should be used, if available. The heaving quality of low velocity explosives will aid in clearing the hole of large boulders. If only high velocity explosives are available, charges should be tamped with water and permitted to freeze. Unless high velocity explosives are thoroughly tamped, they tend to blow out of the borehole.

e. Blasting Ice.

(1) *Access holes.* These are required for water supply and determining the thickness of ice for the computation of safe bearing pressures for aircraft and vehicles. As ice carries much winter traffic, its bearing capacity must be ascertained rapidly when forward movements are required. Small diameter access holes are made by shaped charges. On solid lake ice, the M2A3 penetrates 7 feet and the M3, 12 feet (table XII). These charges will penetrate farther but the penetration distances were tested only in ice approximately 12 feet thick. If the regular standoff is used, a large crater forms at the top, which makes considerable probing necessary to find the borehole. If a standoff of 42 inches or more is used with the M2A3 shaped charge, a clean hole without a top crater is formed. Holes made by the M2A3 average 3½ inches in diameter, while those made by the M3 average 6 inches.

(2) *Ice conditions.* In the late winter after the ice has aged, it grows weaker and changes color from blue to white. Although the structure of ice varies and its strength depends on age, air temperature, and conditions of the original formation, the same size and type of crater is formed regardless of the standoff distance. If the lake or river is not frozen to the bottom and there is a foot or more of water under the ice, the water will rise to within 6 inches of the top after the hole is blown, carrying shattered ice particles with it. This makes the hole easy to clean. If the lake is frozen to the bottom, the blown hole will fill with shattered ice and clearing will be extremely difficult. Under some conditions, shaped charges may penetrate to a depth much less than that indicated in table XII.

(3) *Surface charges.* Surface craters may be made with ammonium nitrate cratering charges or TNT, M1, M2, or M3 demolition blocks. For the best effects, the charges are placed on the surface of cleared ice and tamped on top with snow. The tendency of ice to shatter more readily than soil should be considered when charges are computed.

(4) *Underwater charges.*

(*a*) Charges are placed underwater by first making boreholes in the ice with shaped charges, and then placing the charge below the ice. An 80-pound charge of M3 demolition blocks under ice 4½ feet thick forms a crater 40 feet in diameter. This crater, however, is filled with floating ice particles, and at temperatures around 20° F freezes over in 40 minutes.

(*b*) A vehicle obstacle may be cratered in ice by sinking boreholes 9 feet apart in staggered rows. Charges (tetrytol or plastic) are suspended about 2 feet below the bottom of the ice by means of cords with sticks bridging the tops of the holes. The size of the charge depends upon the thickness of the ice. Only two or three charges are primed, usually one at each end and one at the mid-

dle. The others will detonate sympathetically. An obstacle like this may retard or halt enemy vehicles for approximately 24 hours at temperatures around −24° F.

92. Cratering at Culverts

A charge detonated to destroy a culvert not more than 15 feet deep may, at the same time, produce an effective road crater. Explosive charges should be primed for simultaneous firing and thoroughly tamped with sandbags. Culverts with 5 feet or less of fill may be destroyed by explosive charges placed in the same manner as in hasty road cratering (para 90). Concentrated charges equal to 10 pounds per foot of depth are placed in boreholes at 5-foot intervals in the fill above and alongside the culvert.

93. Antitank Ditch Cratering

a. Construction. In open country, antitank ditches are constructed to strengthen prepared defensive positions. As they are costly in time and effort, much is gained if the excavation can be made by means of cratering charges. To be effective, an antitank ditch must be wide enough and deep enough to stop an enemy tank. It may be improved by placing a log hurdle on the enemy side and the spoil on the friendly side. Ditches are improved by digging the face on the friendly side nearly vertical by means of handtools.

b. Deliberate Cratering Method. The deliberate cratering method outlined in paragraph 89 is adequate for the construction of heavy tank ditches in most types of soil.

c. Hasty Cratering Method. Ditches for medium tanks may be constructed by placing 40 pounds of cratering explosive in 4-foot holes spaced 5 feet apart. This makes a ditch approximately 6 feet deep and 20 feet wide. A heavy antitank ditch may be constructed by placing 50 pounds of cratering explosive in 5-foot holes, and spacing the holes at 5-foot intervals. The ditch will be approximately 8 feet deep and 25 feet wide (para 90).

94. Blasting of Ditches

In combat areas, ditches may be constructed to drain terrain flooded by the enemy or as initial excavations for the preparation of entrenchments. Rough open ditches 2½ to 12 feet deep and 4 to 40 feet wide may be blasted in most types of soils. A brief outline of the method is given below.

a. Test Shots. Before attempting the actual ditching, make test shots to determine the proper depth, spacing, and weight of charges needed to obtain the required results. Make beginning test shots with holes 2 feet deep and 18 inches apart and then increase the size of the charge and the depth as required. A rule of thumb for ditching is to use 1 pound of explosive per cubic yard of earth in average soil.

b. Alinement and Grade. Mark the ditch centerline by transit line or expedient means and drill holes along it. When a transit or hand level is used, the grade of the ditch may be accurately controlled by checking the hole depth every 5 to 10 holes and at each change in grade. In soft ground, the holes may be drilled with a miner's drill or earth auger. Holes are loaded and tamped immediately to prevent cave-ins and insure that the charges are at proper depth. Ditches are sloped at a rate of 6 to 12 inches per 100 feet.

c. Methods of Loading and Firing.

(1) *Propagation method.* By this method only one charge is primed—the charge placed in the hole at one end of the line of holes made to blast the ditch. The concussion from this charge sympathetically detonates the next charge and so on until all are detonated. Only commercial dynamite should be used in this operation. The propagation method is effective, however, only in moist soils or in swamps where the ground is covered by several inches of water. If more than one line of charges is required to obtain a wide ditch, the first charge of each line is primed. The primed hole is overcharged 1 or 2 pounds.

(2) *Electrical method.* Any high explosive may be used in ditching by the electrical firing method which is effective in all soils except sand, regardless of moisture content. Each charge is primed with an electric cap and the caps are connected in series. All charges are fired simultaneously.

(3) *Detonating cord method.* In this ditching method any high explosive may be used. It is effective in any type of soil, except sand, regardless of moisture content. Each charge is primed with detonating cord and connected to a main or ring main line.

Section VII. LAND CLEARING AND QUARRYING CHARGES

95. Introduction

In military operations, construction jobs occur in which demolitions may be employed to advantage. Among these jobs are land clearing, which includes stump and boulder removal, and quarrying. The explosives commonly used are military dynamite and detonating cord. The quantity of explosive used is generally calculated by rule of thumb. Charges may be placed in boreholes in the ground under or at the side of the target, in the target itself, or on top of the target. All charges should be tamped or mudcapped, which is a form of light tamping.

96. Stump Removal

In certain military operations it may be necessary to remove stumps as well as trees. Stumps are of two general types, tap- and lateral-rooted (fig. 111). Military dynamite is the explosive best suited for stump removal. A rule of thumb is to use 1 pound per foot of diameter for dead stumps and 2 pounds per foot for live stumps, and if both tree and stump are to be removed, to increase the amount of explosive by 50 percent. Measurements are taken at points 12 to 18 inches above the ground.

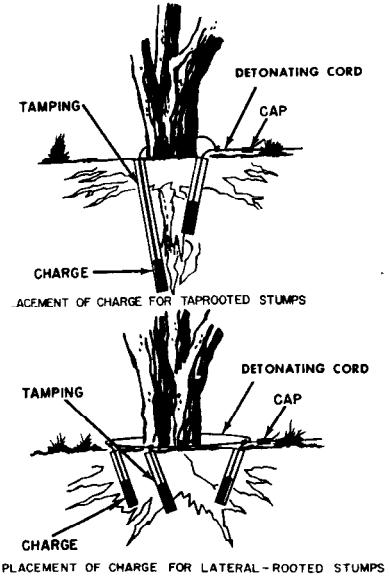


Figure 111. Stump blasting charges.

a. Taproot Stumps. For taproot stumps, one method is to bore a hole in the taproot below the level of the ground. The best method is to place charges on both sides of the taproot to obtain a shearing effect (fig. 111). For best results, tamp the charges.

b. Lateral-Root Stumps. In blasting lateral root stumps, drill sloping holes as shown in figure 111. Place the charge as nearly as possible under the center of the stump and at a depth approximately equal to the radius of the stump base. If for some reason the root formation cannot be determined, assume that it is the lateral type and proceed accordingly.

97. Boulder Removal

In the building of roads and airfields or other military construction, boulders can be removed by blasting. The most practical methods are snakeholing, mudcapping, and blockholing.

a. Snakeholing Method. By this method, a hole large enough to hold the charge is dug under the boulder. The explosive charge is packed under and against the boulder as shown in figure 112. For charge size, see table XIII.

b. Mudcapping Method. For surface or slightly embedded boulders, the mudcapping method is very effective. The charge is placed on top or against the side of the boulder and covered with 10 to 12 inches of mud or clay (fig. 112). For charge size see table XIII.

c. Blockholing Method. This method is very effective on boulders lying on the surface or slightly embedded in the earth. A hole is drilled

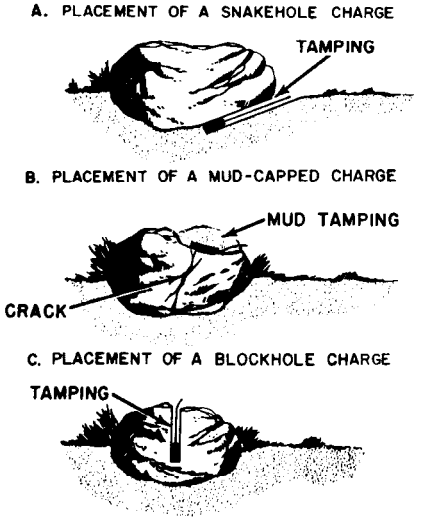


Figure 112. Boulder blasting charges.

on top of the boulder deep and wide enough to hold the amount of explosive indicated in table XIII. The charge is then primed, put into the borehole, and stemmed (fig. 112).

98. Springing Charges

a. Definition and Method. A springing charge is a comparatively small charge detonated in the bottom of a drilled borehole to form an enlarged chamber for placing a larger charge. At times two or more springing charges in succession may be needed to make the chamber large enough for the final charge. Under these conditions at least 30 minutes should be allowed between firing and placing successive charges for the boreholes to cool.

Table XIII. Charge Size for Blasting Boulders

Boulder diameter (ft)	Pounds of explosive required		
	Blockholing	Snakeholing	Mudcapping
1½ (rare)	⅛	½	1
2	⅛	½	1½
3	¼	¾	2
4	⅜	2	3½
5	½	3	6

b. Detonating Cord Wick. This is several strands of detonating cord taped together and used to enlarge boreholes in soils. One strand generally widens the diameter of the hole about 1 inch.

(1) A hole is made by driving a steel rod approximately 2 inches in diameter into the ground to the depth required (para 41c) or by means of a shaped charge. According to the rule of thumb, a hole 10 inches in diameter requires 10 strands of detonating cord. These must extend the full length of the hole and be taped or tied together into a "wick" to give optimum results. The wick may be placed into the hole by an inserting rod or some field expedient. Firing may be done electrically or nonelectrically. An unlimited number of wicks may be fired at one time by connecting them by a detonating cord ring main or main line.

(2) The best results from the use of the detonating cord wick are obtained in hard soil. If successive charges are placed in the holes, excess gases must be burned out and the hole inspected for excessive heat.

99. Quarrying

Quarrying is the extraction of rock in the natural state. Military quarries, generally of the open face type, are developed by the single or multiple bench method. See TM 5–332 for detailed information.

CHAPTER 4

DEMOLITION PROJECTS

Section I. DEMOLITION PLAN

100. Scope

Thus far, this manual has been concerned with methods and techniques in the selection, calculation, priming, placement, and firing of explosives on such materials as steel, concrete, wood, and stone and in earth. This chapter deals with the problems of applying these techniques to the conduct of demolitions projects.

101. Reconnaissance to Develop Demolition Plan

a. Information Required. Thorough reconnaissance is necessary before an effective plan may be made to demolish a target, as reconnaissance provides information in all areas related to the project. Before the demolition of bridges, culverts, and road craters, the following data is provided by reconnaissance.

(1) Situation map sketch (fig. 113) showing the relative position of the objects to be demolished, the surrounding terrain features, and the coordinates of the objects keyed to existing maps.

(2) Side-view sketch of the demolition object. If, for example a bridge is to be blown, a sketch showing the overall dimensions of critical members is necessary (fig. 114).

(3) Cross section sketches, with relatively accurate dimensions of each member to be cut (fig. 114).

(4) A bill of explosives, showing the quantity and kind required.

(5) Sketch of the firing circuits.

(6) List of all equipment required for the demolition.

(7) List of all unusual features of the site.

(8) Estimate of time and labor required to bypass the site.

(9) Estimate of time and labor required for the demolition.

(10) Estimate and sketch of security details required.

SITUATION MAP SKETCH (INCLUDES PRINCIPAL TERRAIN FEATURES; IMMEDIATE AVENUES OF APPROACH; OBSERVATION AND COVER; MAP COORDINATES)

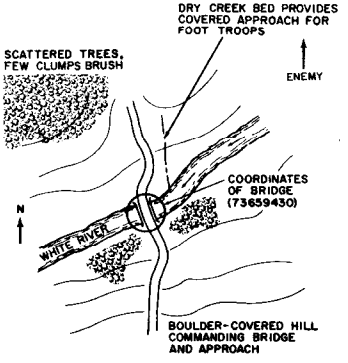

DRY CREEK BED PROVIDES COVERED APPROACH FOR FOOT TROOPS
SCATTERED TREES, FEW CLUMPS BRUSH
ENEMY
COORDINATES OF BRIDGE (73659430)
N
WHITE RIVER
BOULDER-COVERED HILL COMMANDING BRIDGE AND APPROACH

Figure 113. Situation map sketch.

b. Demolition Reconnaissance Record. DA Form 2203–R (Demolition Reconnaissance Record) (fig. 115), together with appropriate sketches, is used to report the reconnaissance of a military demolitions project. This form and the actions listed in *a*, above, are intended primarily for road and bridge demolition. They are also partially applicable to the demolition of almost any other object. In certain instances, the report may require a security classification. The form is reproduced locally on 8- by 10½-inch paper.

102. Demolition Orders

a. Purpose. Three commanders are usually involved in the execution of a demolition proj-

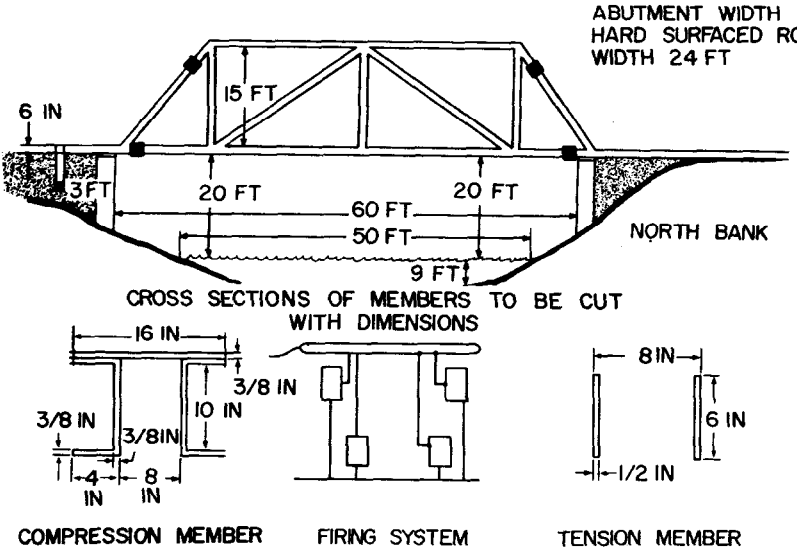


Figure 114. Drawing of object to be demolished.

ect. These are the tactical commander with over-all responsibility and authority to order the firing of the demolition, the commander of the demolition guard, and the commander of the demolition firing party, To assist the commanders in the execution of their responsibilities, two demolition orders are used. These are shown in figure 116, (Orders to the Demolition Guard Commander) and in figure 117, (Orders to the Commander, Demolition Firing Party) (DA Form 2050–R). The procedures that follow are in accord with the agreement between the armed forces of NATO nations and will be complied with by Department of the Army units.

b. Procedures. Each authorized commander, or the tactical commander referred to in *a* above, will—

(1) Establish the requirement and assign the responsibility for a demolition guard and a demolition firing party.

(2) Establish a clear cut channel whereby the order to fire the demolition is transmitted from himself to the commander of the demolition guard and thereby to the commander of the demolition firing party. In the event that no demolition guard is required, this channel must be established between the authorized commander and the commander of the demolition firing party.

(3) Insure that this channel is known and understood by all concerned, and that positive and secure means of transmitting the order to fire are established.

(4) Specify the conditions for executing the demolition as contained in part V of "Orders to the Commander, Demolition Firing Party," and completing part IV of the "Orders to the Demolition Guard Commander."

DEMOLITION RECONNAISSANCE RECORD
(FM 5-25)

SECTION I - GENERAL

1. FILE NO.	2. DML RECON REPORT NO.	3. DATE	4. TIME
411	1	21 JUNE 63	2100

5. RECON ORDERED BY	NAME	GRADE	ORGANIZATION
	JOHN J. SHUBA	CAPT.	954 ENGR BN
6. PARTY LEADER	JOE C. GAY	SFC	RECON SEC

7. MAP REFERENCE STANTON 1:25,000 SHEET NO 5578 IV SE

8. SITE AND OBJECT	9. TIME OBSERVED	10. LOCATION
STEEL TRUSS BRIDGE ACROSS WHITE RIVER ON HWY 1	2200	73659430

11. GENERAL DESCRIPTION SINGLE SPAN STEEL TRUSS CONSTRUCTION, LENGTH OF SPAN 60 FT. WIDTH OF BRIDGE 24 FT. HEIGHT OF TRUSS 15 FT. HEIGHT OF BRIDGE ABOVE WATER 20 FT. CONCRETE ABUTMENTS 35 FT WIDE.

12. NATURE OF PROPOSED DEMOLITION ROTATION METHOD. CUT UPPER AND LOWER CHORD ON BOTH ENDS OF TRUSS ON THE UPSTREAM SIDE OF THE BRIDGE. DESTROY SOUTH SHORE ABUTMENT.

SECTION II - ESTIMATES*

13. EXPLOSIVES REQUIRED

a. TYPES	b. POUNDS	c. CAPS		d. DETONATING CORD	e. FUSE LIGHTERS
		Electric	Nonelectric		
TNT CRATERING CHG	20 LBS 6-40 LB CHGS	4	0	500 FT	0

14. EQUIPMENT REQUIRED

1 - 2½ TON TRUCK

1 - SQUAD DEMO SET.

7 EXTRA REELS OF FIRING WIRE.

15. PERSONNEL AND TIME REQUIRED	PERSONNEL	TIME
	1 SQUAD	1 HR

SECTION III - REMARKS

16. UNUSUAL FEATURES OF SITE

NONE

17. LABOR AND TIME ESTIMATED REQUIRED FOR BYPASS

*Determine availability of Items 13, 14, and 15 before reconnaissance.

DA FORM 2203-R, 1 Mar 67 Previous edition of this form is obsolete.

Figure 115. Demolition reconnaissance record.

CLASSIFICATION

Serial No._____Security Classification_____

ORDERS TO THE DEMOLITION GUARD COMMANDER

Notes: 1. This form will be completed and signed before it is handed to the Commander of the Demolition Guards.

2. In completing the form, all spaces must either be filled in or lined out.

3. The officer empowered to order the firing of the demolition is referred to throughout as the "Authorized Commander".

From_____To_____

PART I - PRELIMINARY INSTRUCTIONS

1.a. Description of target_____

b. Location:

Map Name and Scale_____Sheet No._____

Grid Reference_____

c. Codeword or codesign (if any) of demolition target._____

2.The Authorized Commander is_____ (give appointment only). If this officer should delegate his authority, you will be notified by one of the methods shown in paragraph 4, below.

3. The DEMOLITION FIRING PARTY has been/will be provided by_____

4. All messages, including any codewords or codesign (if any) used in these orders, will be passed to you by:

a. Normal command wireless net, or

b. Special liaison officer with communications direct to the Authorized Commander, or

CLASSIFICATION

Figure 116. Orders to the Demolition Guard Commander. ①

CLASSIFICATION (Cont'd)

c. Telephone by the Authorized Commander, or

d. The Authorized Commander personally, or

e. _____

(Delete those NOT applicable)

Note: All orders sent by message will be prefixed by the code-word or codesign (if any) at paragraph 1.c., and all such messages must be acknowledged.

CLASSIFICATION (Cont'd)

Figure 116—Continued. ②

NATO - UNCLASSIFIED

PART II - CHANGING STATES OF READINESS

5. The demolition will be prepared initially to the State of Readiness_____by_____hours on_____(date).

6. On arrival at the demolition site, you will ascertain from the commander of the demolition firing party the estimated time required to change from State "1" (SAFE) to State "2" (ARMED). You will ensure that this information is passed to the Authorized Commander and is acknowledged.

7. Changes in the State of Readiness from State "1" (SAFE) to State "2" (ARMED) or from State "2" to State "1" will be made only when so ordered by the Authorized Commander. However, the demolition may be ARMED in order to accomplish emergency firing when you are authorized to fire it on your own initiative.

8. A record of the changes in the State of Readiness will be entered by you in the table below, and on the firing orders in possession of the commander of the demolition firing party.

State of Readiness ordered "1" (SAFE) or "2" (ARMED)	Time & date change to be completed	Authority	Time & date of receipt of order

Note: If the order is transmitted by an officer in person, his signature and designation will be obtained in the column headed "Authority".

9. You will report completion of all changes in the State of Readiness to the Authorized Commander by the quickest means.

PART III - ORDERS FOR FIRING THE DEMOLITION

10. The order for firing the demolition will be passed to you by the Authorized Commander.

NATO - UNCLASSIFIED

Figure 116—Continued. ®

NATO - UNCLASSIFIED (Cont'd)

PART III - ORDERS FOR FIRING THE DEMOLITION

11. On receipt of this order you will immediately pass it to the commander of the demolition firing party on his demolition Orders form ("Orders to the Commander of the Demolition Firing Party").

12. After the demolition has been fired you will report the results immediately to the Authorized Commander.

13. In the event of a misfire or only partially successful demolition you will give the firing party protection until such time as it has completed the demolition and report again after it has been completed.

NATO - UNCLASSIFIED (Cont'd)

Figure 116—Continued. ⓒ

NATO - UNCLASSIFIED

PART IV - EMERGENCY FIRING ORDERS

Notes: 1. One sub-paragraph of paragraph 14 must be deleted.

2. The order given herein can only be altered by the issue of a new form, or, in emergency by the appropriate order (or codeword if used) in Part V.

14.a. You will order the firing of the demolition only upon the order of the Authorized Commander.

OR

b. If the enemy is in the act of capturing the target, and/or munition, you will order the firing of the demolition on your own initiative.

PART V - CODEWORDS (IF USED)

	Action to be taken	Codeword (if used)
a.	Change State of Readiness from "1" to "2" (See paragraph 7)	
b.	Change State of Readiness from "2" to "1" (See paragraph 7)	
c.	Fire The Demolition (see paragraph 10)	
d.	Paragraph 14a is now cancelled. You are now authorized to fire the demolition if the enemy is in the act of capturing it.	

NATO - UNCLASSIFIED

Figure 116—Continued. ⑤

PART IV - EMERGENCY FIRING ORDERS

e.	Paragraph 14b is now cancelled. You will order the firing of the demolition only upon the order of the Authorized Commander.	Codeword (if used)
f.	Special authentication instructions, if any.	

PART VI

Signature of officer issuing these orders_____

Name (printed in capital letters)_____

Rank_____Appointment_____

Time of issue_____hours,_____(date).

Figure 116—Continued ⑨

NATO - UNCLASSIFIED

PART VII - DUTIES OF THE COMMANDER

OF THE DEMOLITION GUARD

15. You are responsible for:-

a. Command of the demolition guard and the demolition firing party.

b. The safety of the demolition from enemy attack, capture, or sabotage.

c. Control of traffic and refugees.

d. Giving the orders to the demolition firing party in writing to change the state of readiness.

e. Giving the order to the demolition firing party in writing to fire the demolition.

f. After the demolition, reporting on its effectiveness to the Authorized Commander.

g. Keeping the Authorized Commander informed of the operational situation at the demolition site.

16. You will acquaint yourself with the orders issued to the Commander of the Demolition Firing Party and with the instructions given by him.

17. The Demolition Guard will be so disposed as to ensure at all time complete all-round protection of the demolition against all types of attack or threat.

18. The Commander of the Demolition Firing Party is in technical control of the demolition. You will agree with him on the site of your Headquarters and of the firing point. These should be together whenever practicable. When siting them you must give weight to the technical requirements of being able to view the demolition and have good access to it from the firing point.

NATO- UNCLASSIFIED

Figure 116—Continued. ⑦

PART VII - DUTIES OF THE COMMANDER

OF THE DEMOLITION GUARD

19. You will nominate your deputy forthwith and compile a seniority roster. You will ensure that each man knows his place in the roster, understands his duties and knows where to find this form if you become a casualty or are unavoidably absent. The seniority roster must be made known to the Commander of the Demolition Firing Party.

20. Once the state of readiness "2 ARMED" has been ordered, either you or your deputy must always be at your Headquarters so that orders can be passed on immediately to the Commander of the Demolition Firing Party.

Figure 116—Continued. ®

SECURITY CLASSIFICATION

ORDERS TO THE COMMANDER, DEMOLITION FIRING PARTY	SERIAL NUMBER

NOTE: Parts I, II and III will be completed and signed before this form is handed to the commander of the Demolition Firing Party. Paragraphs 4 and 5 can only be altered by the authority issuing these orders. In such cases a new form will be issued and the old one destroyed.

FROM:	TO:

PART I - ORDERS FOR PREPARING AND CHARGING THE DEMOLITION TARGET

1a. DESCRIPTION

b. LOCATION			c. CODE WORD OF DEMOLITION TARGET (If any)
MAP NAME AND SCALE	SHEET NO.	GRID REFERENCE	

d. ATTACHED PHOTOGRAPHS AND SPECIAL TECHNICAL INSTRUCTIONS

2. THE DEMOLITION GUARD IS BEING PROVIDED BY (Unit)

3. YOU WILL PREPARE AND CHARGE THE DEMOLITION TARGET TO THE STATE OF READINESS _____ BY _____ HOURS ON (Date)_____
ANY CHANGES MAY ONLY BE MADE ON THE ORDER OF THE ISSUING AUTHORITY, OR BY THE OFFICER DESIGNATED IN PARAGRAPH 4d AND WILL BE RECORDED BELOW.

STATE OF READINESS ORDERED "1(SAFE)" or "2(ARMED)"	TIME AND DATE CHANGE TO BE COMPLETED	AUTHORITY	TIME AND DATE OF RECEIPT OF ORDER

NOTE: All orders received by message will be verified by the code word at Paragraph 1c. If the order is transmitted by an officer in person, his signature and designation will be obtained in the Column headed "Authority".

PART II - ORDERS FOR FIRING

NOTE: The officer issuing these orders will strike out the subparagraphs of Paragraphs 4 and 5 which are not applicable. When there is a demolition guard, Paragraph 4 will always be used and Paragraph 5 will always be struck out.

4a. YOU WILL FIRE THE DEMOLITION AS SOON AS YOU HAVE PREPARED IT.
b. YOU WILL FIRE THE DEMOLITION AT _____ HOURS ON (Date)_____.
c. YOU WILL FIRE THE DEMOLITION ON RECEIPT OF THE CODE WORD _____.
d. YOU WILL FIRE THE DEMOLITION WHEN THE OFFICER WHOSE DESIGNATION IS _____ HAS SIGNED PARAGRAPH 8 BELOW.

EMERGENCY FIRING ORDERS (ONLY applicable when there is NO demolition guard)

5a. YOU WILL NOT FIRE THE DEMOLITION IN ANY CIRCUMSTANCES EXCEPT AS ORDERED IN PARAGRAPH 4 ABOVE.
b. YOU WILL FIRE THE DEMOLITION ON YOUR OWN INITIATIVE IF THE ENEMY IS IN THE ACT OF CAPTURING IT.

DA FORM 2050-R, 1 NOV 57 SECURITY CLASSIFICATION

Figure 117. Orders to the Commander, Demolition Firing Party. ①

SECURITY CLASSIFICATION

PART III - ORDERS FOR REPORTING

6. AFTER FIRING THE DEMOLITION YOU WILL IMMEDIATELY REPORT RESULTS TO THE OFFICER WHO ORDERED YOU TO FIRE. IN THE EVENT OF A PARTIAL FAILURE YOU WILL WARN HIM, AND IMMEDIATELY CARRY OUT THE WORK NECESSARY TO COMPLETE THE DEMOLITION

7. FINALLY, YOU WILL IMMEDIATELY REPORT THE RESULTS TO YOUR UNIT COMMANDING OFFICER (See Paragraph 13.)

SIGNATURE OF OFFICER ISSUING THESE ORDERS	NAME (In capitals) DESIGNATION	TIME OF ISSUE	DATE OF ISSUE

PART IV - ORDER TO FIRE

8. BEING EMPOWERED TO DO SO, I ORDER YOU TO FIRE NOW THE DEMOLITION DESCRIBED IN PARAGRAPH 1.

SIGNATURE	NAME (In capitals) DESIGNATION	TIME	DATE

PART V - GENERAL INSTRUCTIONS (Read These Instructions Carefully)

9. YOU ARE IN TECHNICAL CHARGE OF THE PREPARATION, CHARGING AND FIRING OF THE DEMOLITION TARGET DESCRIBED. YOU WILL NOMINATE YOUR DEPUTY FORTHWITH AND COMPILE A SENIORITY ROSTER OF YOUR PARTY. YOU WILL INSURE THAT EACH MAN KNOWS HIS PLACE IN THE ROSTER, UNDERSTANDS THESE INSTRUCTIONS, AND KNOWS WHERE TO FIND THIS FORM IF YOU ARE HIT OR UNAVOIDABLY ABSENT. YOU WILL CONSULT WITH THE COMMANDER OF THE DEMOLITION GUARD ON THE SITING OF THE FIRING POINT.

10. YOU MUST UNDERSTAND THAT THE COMMANDER OF THE DEMOLITION GUARD (where there is one) IS RESPONSIBLE FOR:
   a. OPERATIONAL COMMAND OF ALL THE TROOPS AT THE DEMOLITION SITE. (You are therefore under his command.)
   b. PREVENTING THE CAPTURE OF THE DEMOLITION SITE, OR INTERFERENCE BY THE ENEMY WITH DEMOLITION PREPARATIONS.
   c. CONTROLLING ALL TRAFFIC AND REFUGEES.
   d GIVING YOU THE ORDER TO CHANGE THE STATE OF READINESS FROM "1(SAFE)" TO "2(ARMED)" OR BACK TO "1(SAFE)" AGAIN. YOU WILL INFORM HIM OF THE TIME REQUIRED FOR SUCH A CHANGE.
   e. PASSING TO YOU THE ACTUAL ORDER TO FIRE.

11. WHEN THERE IS NO DEMOLITION GUARD AND YOU ARE INSTRUCTED IN PARAGRAPH 4 TO ACCEPT THE ORDER TO FIRE FROM SOME PARTICULAR OFFICER, IT IS IMPORTANT THAT YOU ARE ABLE TO IDENTIFY HIM.

12. IF YOU GET ORDERS TO FIRE, OTHER THAN THOSE LAID DOWN IN PARAGRAPH 4, YOU SHOULD REFER THEM TO THE DEMOLITION GUARD COMMANDER OR, IF THERE IS NO DEMOLITION GUARD COMMANDER, TO YOUR IMMEDIATE SUPERIOR. IF YOU CANNOT DO THIS, YOU WILL ONLY DEPART FROM YOUR WRITTEN INSTRUCTIONS WHEN YOU ARE SATISFIED AS TO THE IDENTITY AND OVERRIDING AUTHORITY OF WHOEVER GIVES YOU THESE NEW ORDERS, AND YOU WILL GET HIS SIGNATURE IN PARAGRAPH 8 WHENEVER POSSIBLE.

13. THE REPORT TO YOUR UNIT COMMANDING OFFICER, AS CALLED FOR IN PARAGRAPH 7, SHOULD CONTAIN THE FOLLOWING INFORMATION (where applicable):
   a. IDENTIFICATION REFERENCE OF DEMOLITION.
   b. MAP REFERENCE.
   c. TIME AND DATE WHEN DEMOLITION WAS FIRED.
   d. EXTENT OF DAMAGE ACCOMPLISHED, INCLUDING:
      ESTIMATED WIDTH OF GAP) IN CASE OF A BRIDGE
      NUMBER OF SPANS DOWN)
      SIZE AND LOCATION OF CRATERS IN A LOAD OR RUNWAY.
      MINES LAID.
   e. SKETCH SHOWING EFFECT OF DEMOLITION.

SECURITY CLASSIFICATION

Figure 117—Continued. ⑤

c. Orders to the Demolition Guard Commander. The authorized commander completes and signs this form. The order is written in seven parts, each of which is self-explanatory.

d. Orders to the Commander, Demolition Firing Party. In addition to those items listed in *b* above, the authorized commander designates the unit or individual responsible for the preparation of these orders. This unit or individual will complete and sign parts I through III and pass the order to the commander of the demolition firing party. Part IV will be completed upon detonation of the demolition (fig. 117).

e. Definitions. The states of readiness (*safe and armed*) referred to in part I of the Order to the Commander, Demolition Firing Party, and in part II of the Order to the Demolition Guard Commander, are described as follows:

(1) "1 (*Safe*)." The explosive charges are prepared and securely fixed to the target and are safe against premature firing. All firing circuits and accessories have been checked, are in proper operating condition, and are ready to be attached to charges. If detonating cord is used it may be attached to demolition charges; however, detonators will not be attached to detonating cord ring mains or main lines until the state of readiness is changed to "armed."

(2) "2 (*Armed*)." The demolition is ready for immediate firing. The risk of premature detonation is accepted.

f. Disposition of Orders. After the demolition has been fired, one copy of the orders will be retained by the headquarters of the issuing authority and one by the commander of the demolition firing party.

Section II. TECHNIQUES COMMON TO MOST DEMOLITIONS

103. Types of Military Demolitions

There are three types of demolitions applicable to tactical situations—reserved, deliberate, and hasty.

a. Reserved Demolitions. These are specifically controlled at a command level appropriate to the tactical or strategic plan. Reserved demolitions are usually in place, "ready and waiting," in the "safe" condition.

b. Deliberate Demolitions. Deliberate demolitions are used when enemy interference during preparations is unlikely and there is sufficient time for thorough reconnaissance and careful preparation. Deliberate preparation permits economy in the use of explosives, since time permits accurate calculation and positive charge placement to obtain the effects required.

c. Hasty Demolitions. Hasty demolitions are used when time is limited and economy of explosives is secondary to speed. In all cases, common sense and good judgment must be exercised to prevent waste. In the preparation of demolition projects in forward areas where a surprise raid by hostile forces is possible, a priority should be given to each charge. Although this procedure is relatively time consuming, it causes maximum damage to the project in relation to the time required, even though enemy interference might prevent completion of the job. Each charge is primed as it is placed; for if charges are all placed first and then primed, it is possible that enemy interference prior to the act of priming might stop the work before any damage is done. The use of dual detonating cord ring main lines and branch lines is recommended for all frontline demolition projects (para 64–70).

104. Nuclear Weapons Demolitions

Atomic demolition munitions (ADM) may be effectively employed to create obstacles and to destroy and deny military facilities or installations. They have the capability of creating large radioactive craters with little preparatory effort. The residual radiation and fallout hazards require consideration; however, the use of small yields minimizes the fallout hazard and area of residual contamination. The ODM, like conventional hand-placed charges, has a primary advantage of no delivery error, which permits the use of minimum yield for a given target. This is of particular importance in producing craters or for destruction through cratering effects since the radius of cratering effects of atomic weapons is relatively small in comparison with other effects. No further information, see FM 5–26.

105. Supplementing Demolition Obstacles

Nuisance mining and charges with delay fuses are a very potent means of increasing the effects of demolition projects. The area to be mined should include the facility to be destroyed, the ground where a replacement structure or remedial work will likely be performed, working party bivouacs, and alternate sites. Thus, for a demolished bridge, the dropped spans and abutments should be mined to impede removal or recovery; suitable sites for a floating bridge or ford should be mined to prevent ready use; and locations likely to be selected for material storage, equipment parks, or bridge unit bivouacs should also be well mined and boobytrapped.

Section III. BRIDGE DEMOLITION

106. Extent of Demolition

There is no rule of thumb or regulation to indicate the optimum extent of demolition of bridges. It is determined after investigation and analysis of specific conditions.

a. Complete Bridge Demolition. Complete demolition leaves nothing of the old bridge suitable for use in a new bridge. Debris is left on the site where its removal will require much hazardous work before any kind of crossing can be installed. However, when enough demolition is accomplished to force the enemy to select another site for a temporary bridge as a substitute for the damaged bridge, further demolition is unnecessary. Too, a permanent structure is not likely to be replaced in kind during wartime. However, where the terrain is such that the existing bridge site is needed for a new structure, even a temporary one, demolition in greater proportions may be justified.

b. Partial Demolition.

(1) *Method.* Bridges are generally demolished to create obstacles that delay the enemy. This seldom requires complete destruction. Unless a denial operation is in effect, the demolition method chosen should permit the economical reconstruction of the bridge by friendly troops at a later date. Frequently the necessary delay can be obtained by only blasting a gap too long to be spanned by the prefabricated bridging available to the enemy. This gap should be located where the construction of an intermediate support is difficult or impossible. A high and relatively slender bridge component may be demolished by cutting one side so that it topples into a mass of broken and twisted material. The destruction of massive bridge components, however, requires large expenditures of explosive, time, equipment, and effort that may not be profitable. In many cases on major bridges, the destruction of any component that can easily be replaced may not be justified.

(2) *Factors determining the extent of destruction.* Factors that determine the extent of destruction needed for a project are as follows:

(*a*) The tactical and strategical situations that indicate the length of time the enemy must be delayed, the time available for demolition, and the extent of denial to be accomplished.

(*b*) The likelihood that friendly forces may reoccupy the area and require the use of the bridge.

(*c*) The results to be obtained by the expenditure of labor and materials compared with the results that may be obtained elsewhere with the same effort.

(*d*) The manpower, equipment, and kinds and quantities of explosives available.

107. Parts of Fixed Bridges

The ordinary fixed bridge is divided into two main parts; the lower part or substructure, and the upper part or superstructure (fig. 118).

a. Substructure. The substructure consists of the parts of the bridge that support the superstructure. There are two kinds of supports: end supports or abutments and intermediate supports, or piers or bents. The parts of the substructure are—

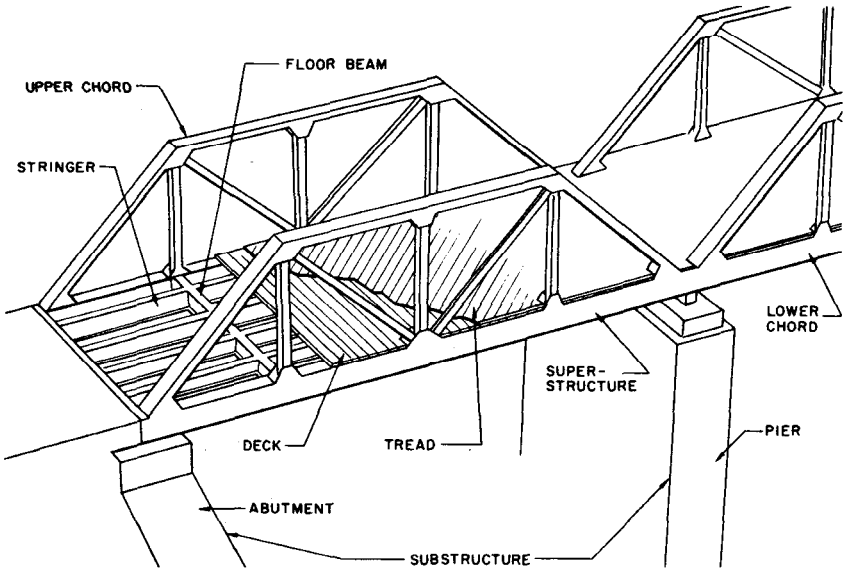


Figure 118. Parts of fixed bridge.

(1) *Abutment.* The ground supports at the ends of a bridge are called abutments. These may be constructed of concrete, masonry, steel, or timber and may include retaining walls or an end dam.

(2) *Footing.* A footing is that part of any bridge support that rests directly on the ground. It distributes the load over an area wide enough to keep the support from sinking into the ground.

(3) *End dam.* An end dam is a retaining wall of concrete, wood, or other material at the end of a bridge that supports the bank and keeps the approach road from caving in.

(4) *Intermediate support.* An intermediate support is a support placed beneath a bridge between the abutments. It may be a pier of masonry or concrete, cribbing, several pile or trestle bents constructed as a unit, or a single pile or trestle bent.

b. Superstructure. The superstructure includes the flooring, stringers, floor beams, and any girders or trusses that make up the total part of the bridge above the substructure (fig. 118).

(1) *Span.*

(a) *Simple.* Simple spans have stringers that extend only from one support to the next.

(b) *Continuous.* Continuous spans have beams that extend over one or more intermediate supports.

(2) *Truss.* A truss consists of these principal elements:

(a) *Lower chord.* The lower chord is the lower member in a panel of a truss that runs parallel to the deck.

(*b*) *Upper chord.* The upper chord includes the upper members in the panel.

(3) *Stringers.* Stringers run longitudinally with the bridge and directly support the deck.

(4) *Deck and tread.* The deck is the floor of the bridge and the tread, the top surface material.

108. Planning Bridge Demolitions

a. Structural Characteristics. The demolition of bridges must be carefully planned, as bridges have a great variety of superstructures made of steel, timber, or masonry and various types of substructures made of these materials. The size and placement of the charge, therefore, depends on the characteristics of the individual bridge structure.

b. General Procedures. Some general procedures apply to most bridge demolition projects; *for example:* if charges are placed under the bridge roadway, special precautions must be taken to insure that the charges will not be shaken loose or initiated by traffic on the bridge. The following general points apply to the demolition of most or all of the bridge structures mentioned and described below.

(1) Hasty charges, which must be placed first because of enemy interruption, should be located carefully, if possible, so that they may be included later on into the deliberate preparation of the bridge.

(2) It is often possible either to economize on the use of explosives or to improve the thoroughness of the demolition by blasting several times rather than only once. When conditions permit, this procedure should be considered.

(3) Tension members are more difficult to repair than compression members, because the latter may sometimes be replaced by cribbing while the former almost always require steel riveting or welding. Thus tension members should be given priority.

(4) When bridges over railways or canals are to be destroyed, the demolition should be so planned that any temporary intermediate piers that might be erected to repair the structure will be located where they will block traffic on the railroad or canal.

(5) Any long steel members that require cutting in only one place to demolish the bridge should be further damaged to prevent their ready salvage by recutting or splicing. It is not necessary to cut such members completely in two at other points to accomplish this. A number of small charges properly located will damage the upper flange, the lower flange, and the web, which will make repair difficult and uneconomical. The twisting of such members in dropping the span and any other feasible method of further destruction should also be considered.

(6) The nature of the terrain under the bridge is of great importance to the success of the demolition. If the distance from the river bed, for example, to the bridge is adequate, the weight of the bridge may be exploited to assist in its destruction (fig. 127).

109. Destruction of Substructures

a. Concrete and Masonry Abutments.

(1) *Charges in fill behind abutment.* The placing of charges in the fill behind an abutment has the advantages of economy in the use of explosives and of concealment of the charges from the enemy until they are detonated. This method also has its disadvantages, as the charges are difficult to place. Where speed is required, charges are not placed behind the abutment if the fill is known to contain large rocks. If the bridge approach is an embankment, the most practical method may be to place explosive charges in a tunnel driven into the side.

(*a*) *Abutments 5 feet or less in thickness and 20 feet or less in height* (fig. 119). Such abutments are demolished by a line of 40-pound cratering charges placed on 5-foot

centers in holes 5 feet deep and 5 feet behind the face of the abutment ("triple-nickel-forty"). The first hole is placed 5 feet from one side of the abutment and this spacing is continued until a distance of 5 feet or less is left from the last hole to the other side of the abutment. The formula for computing the number of charges is

$N = \frac{W}{5} - 1$, where N = number of charges and W the width of the abutment. If the wing walls are strong enough to support a rebuilt or temporary bridge, they too should be destroyed by placing charges behind them in a similar fashion.

(*b*) *Abutments more than 5 feet thick and 20 feet or less in height.* Such abutments are destroyed by breaching charges placed in contact with the back of the abutment (fig. 120). These charges are calculated by means of the breaching formula, $P = R^3KC$ (para 86*a*), using the abutment thickness as the breaching radius R. The charges are placed at a depth equal to or greater than R. The number of charges and their spacing are determined by the formula $N = \frac{W}{2R}$.

(2) *Combination charges.* A combination of external breaching charges and fill charges may be used to destroy abutments more than 20 feet high. Breaching charges placed along the bottom of the abutment face should be fired simultaneously with the charges in the fill behind the abutment. These fill charges may be breaching charges as explained in (1) (*b*) above, or the "triple-nickel-forty" charges depending on the abutment thickness. This tends to overturn and completely destroy the abutment.

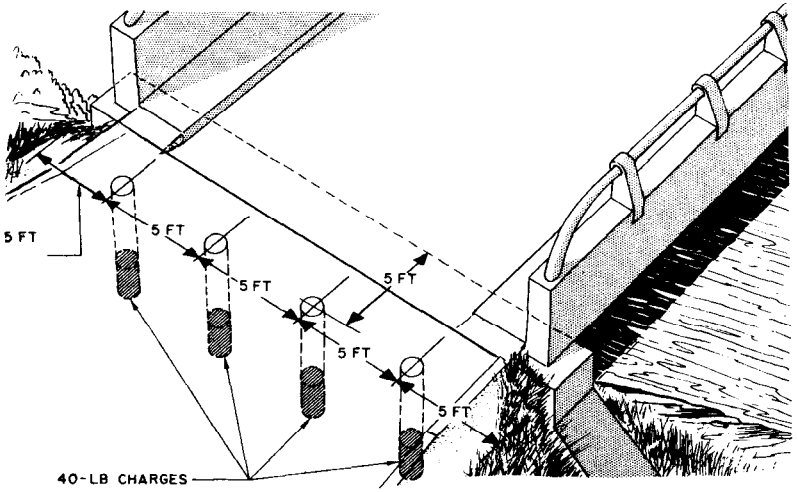


Figure 119. Charges placed in fill behind reinforced concrete abutment 5 feet thick or less.

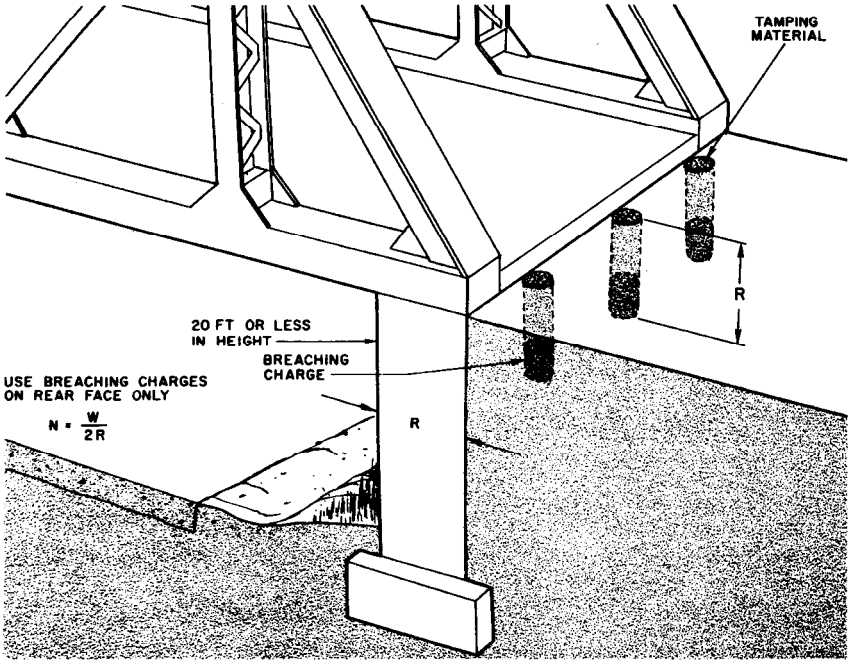


Figure 120. Charges placed in fill behind reinforced concrete abutment more than 5 feet thick.

b. Intermediate Supports.

(1) *Effectiveness.* The destruction of one or more intermediate supports of a multispan bridge is usually the most effective method of demolition (fig. 121). The destruction of one support will collapse the spans on each side of it, so that destruction of only alternate intermediate supports is sufficient to collapse all spans. For repair this will require either the replacement of those supports or the construction of long spans.

(2) *Concrete and masonry piers.* Concrete and masonry piers are demolished either by internal or external charges (fig. 121). Internal charges require less explosive than external charges, but because they require a great amount of equipment and time for preparation, they are seldom used unless explosives are scarce or the pier has built-in demolition chambers. The number of charges required is calculated by the formula $N = \frac{W}{2R}$ (para 87*b*). The size of each charge is calculated by the breaching formula, $P = R^3KC$ (para 86*a*).

(*a*) *Internal charges.* Plastic (C3 or C4), dynamite, and other explosives are satisfactory for internal charges. All charges of this type should be thoroughly tamped with blunt wooden tamping sticks, *not* with steel bars or tools. If there are no demolition chambers, charges are placed in boreholes, which are blasted by means of shaped charges or drilled with pneumatic or hand tools. A 2-inch diameter borehole holds about 2 pounds of explosive per foot of length or depth. The steel reinforcing bars make drilling in heavily reinforced concrete impractical, however.

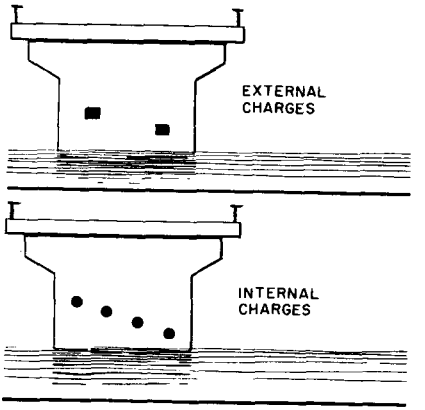
(*b*) *External charges.* External charges may be placed at the base of a pier or higher and spaced not more than twice the breaching radius (para 86*b*) apart. All external charges should be thoroughly tamped with earth and sandbags if time and the size, shape, and location of the target permit.

110. Stringer Bridges

a. Use. The stringer bridge (fig. 122) is the most common type of fixed bridge found in most parts of the world. It is frequently used in conjunction with other types of spans. The stringers are the load-carrying members, while the floor is dead load. Stringers may be timber, concrete, rolled steel sections, or plate girders.

b. Simple Spans. In simple span stringer bridges, the stringers extend only from one support to the next. The method of destruction for this type of superstructure is to place the charges so that they cut the stringer into unequal lengths in order to prevent reuse (fig. 122).

c. Continuous Spans. Continuous spans have continuous lateral supports that extend over one or more intermediate supports. Because the spans are stiffer over piers than at midspan, they may frequently remain in place even though completely cut at midspan. Steel or reinforced concrete is commonly used for such lateral supports. Continuous steel beams, girders, or trusses may be identified readily because they are either the same depth or deeper over piers than elsewhere, and there is no break or weak section over the supports. The superstructure may be demolished by cutting *each member* in *two* places *between supports* and then dropping completely the portion between the cuts. Also, the span may be cut in unequal portions on the sides of the support for overbalancing and falling. Continuous con-



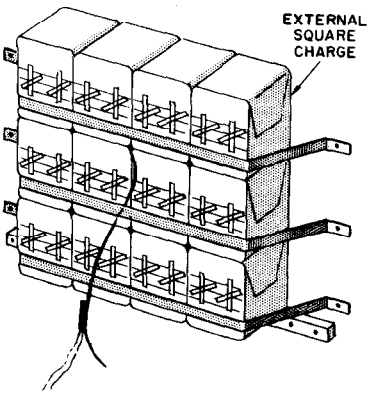


Figure 121. Charges placed on intermediate supports.

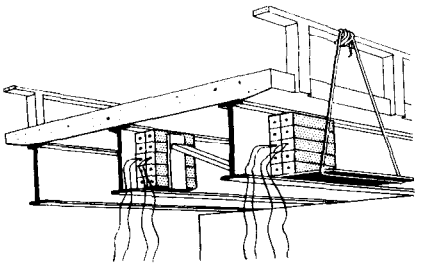


Figure 122. Placement of charges on steel stringer bridge.

crete T-beams or continuous concrete slab bridges may be recognized by the absence of construction or expansion joints over the supports.

111. Slab Bridges

The superstructure of a slab bridge consists of a flat slab support at both ends (fig. 123). This is usually made of reinforced concrete, but may also be of laminated timber or a composite section of timber with a thin concrete wearing surface. If they are simple spans, the superstructure may be destroyed by the use of a single row of charges placed either across the roadway or underneath the span. The breaching formula is used for reinforced concrete slabs; and the timber-cutting (external charge) formula is used for laminated timber. On reinforced concrete slabs, the charges are placed twice the breaching radius apart; and on laminated timber, twice the slab thickness apart. Continuous slab spans must be cut in two places to insure the dropping of the slab or cut in places over the support to provide overturning by unequal weight distribution.

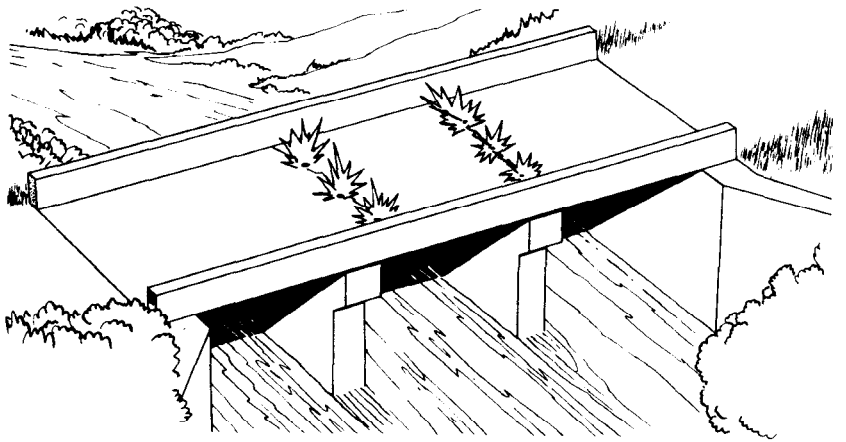


Figure 123. Placement of charges on slab bridge.

112. Concrete T-Beam Bridges

A T-beam bridge is a heavily reinforced concrete stringer bridge with the floor and stringer made in one piece. The floor acts as part of the beam. This type is heavily reinforced. T-beam bridges are generally simple span or continuous span.

a. Charge Placement on Simple Span. Simple span T-beam bridges are destroyed by explosives calculated and placed by the pressure formula or breaching formula.

b. Charge Placement on Continuous Span.

Continuous span T-beam bridges are destroyed by breaching. Charges calculated by the breaching formula are usually placed under the deck in order to use the thickness of the beam *R*. Continuous T-beam bridges may be recognized by the haunching or deepening of the section adjacent to the interior supports. According to conditions, it may be necessary to demolish the piers, demolish the junction between span and pier, or remove all spans by cutting them at approximately one-quarter of their length from each end between supports. Breaching charges are used in all these cases. They may be placed on the roadway, or underneath it if the bridge must be used after the charges have been prepared (fig. 124).

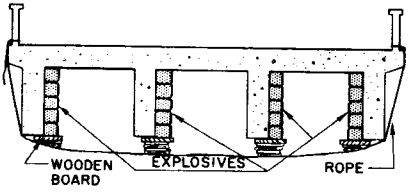


Figure 124. Placement of charges on continuous T-beam span.

113. Concrete Cantilever Bridges

a. Description. Concrete cantilever bridges are identified by the construction joints that appear in the span but not over the piers. Figure 125 shows a cantilever bridge with a suspended span and figure 126, a cantilever bridge without a suspended span.

b. Concrete Cantilever Bridges with Suspended Span. The superstructure of this bridge may be demolished by cutting each cantilever arm adjacent to the suspended span. If a large gap is desired, the cantilever arms should be cut in such a way as to drop the cantilever arms and the suspended spans (fig. 125).

c. Concrete Cantilever Bridges without Suspended Span. As in the bridges above, the superstructure of a cantilever bridge without suspended span is demolished by destroying the cantilever action and unbalancing the cantilever arms (fig. 126). A bridge of this type must be studied to determine the function of the members. Otherwise the charges may not be properly placed.

114. Truss Bridges

a. Description. A truss is a jointed frame structure consisting of straight members (steel or timber) so arranged that the truss is loaded only at the joints. Trusses may be laid below the roadway of the bridge (deck-type trusses) or partly or completely above the roadway (through-type trusses).

b. Single Span Trusses. Single span trusses extend only from pier to pier, usually having a pin joint on one end and a sliding connection at the other. Simple span trusses may be destroyed by any of the following methods:

(1) Cut the upper chord and lower chords at both ends of one truss in each span on the upstream side. This causes the bridge to roll over; thereby twisting the other truss off its support (rotation method). The height of the bridge above the riverbed, however, must permit this. Place the charges on the upper chord so that upon firing the severed upper member will not hang on the lower member and the gap will extend the width of the roadway (fig. 127). If the truss is too small and too light to twist free, both ends of both trusses on each span should be cut or the method described in (2) below should be used.

(2) Cut the upper chords, lower chords, and diagonals of both trusses and the roadway midspan (fig. 128). This is a more complete demolition and makes the reuse of the truss extremely difficult.

(3) Cut both trusses into segments (fig. 129).

c. Continuous Span Trusses. Continuous span trusses are usually extended over two spans, rarely over three. The heaviest chord sections and the greatest depth of truss are located over the intermediate supports. One method of demolition is shown in figure 130. In general, aside from the exact location of charges, the methods given for the destruction of simple span trusses are applicable to con-

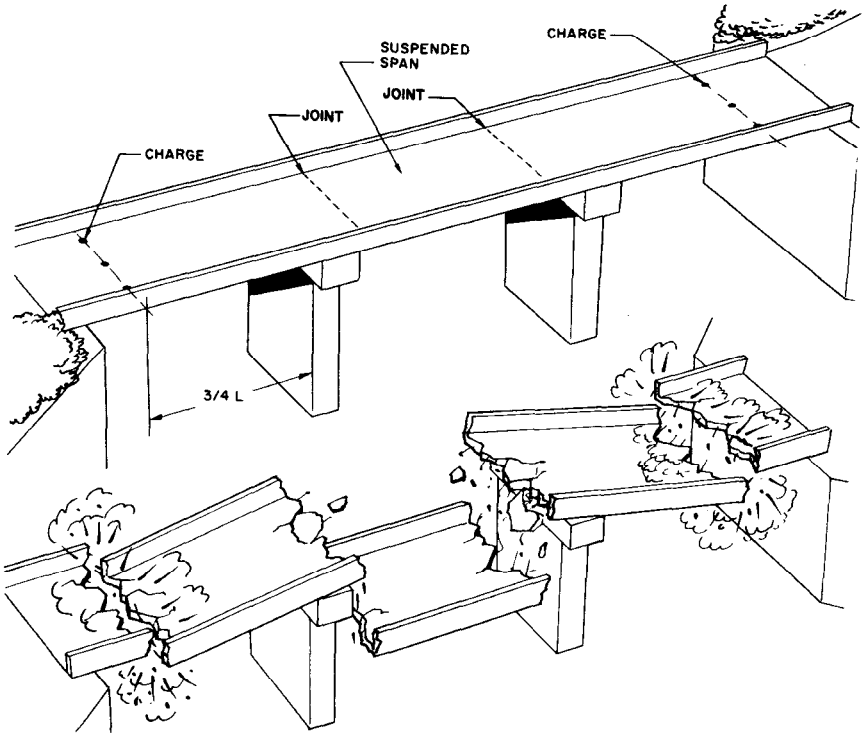


Figure 125. Placement of charges on concrete cantilever bridge with suspended span.

tinuous spans. Care must be taken to make the cuts so that the bridge becomes unbalanced and collapses.

115. Cantilever Truss Bridges

a. Description. Cantilever truss bridges obtain their strength by having a much deeper, stronger beam section over the piers, or in effect, two "arms" that reach partially or completely across the adjacent spans. As cantilever truss bridges are a modification or refinement of continuous truss or continuous beam bridges, the demolition methods given in paragraphs 112 and 114 apply.

b. Cantilever Truss Bridges with Suspended Span. Cantilever truss bridges with suspended span are invariably major bridges having single suspended spans. The suspended spans are hung from the ends of adjacent cantilever arms by means of hinges, hangers, or sliding joints. Cutting at these junctions causes these spans to drop out of the bridge (fig. 131). These may be identified by a thorough study of the bridge structure. Additional steel members may be provided for stabilization but carry no load. The cantilever arms may also be destroyed by the method described in *c* below.

c. Cantilever Truss Bridge Without Suspended Span. To destroy a cantilever truss

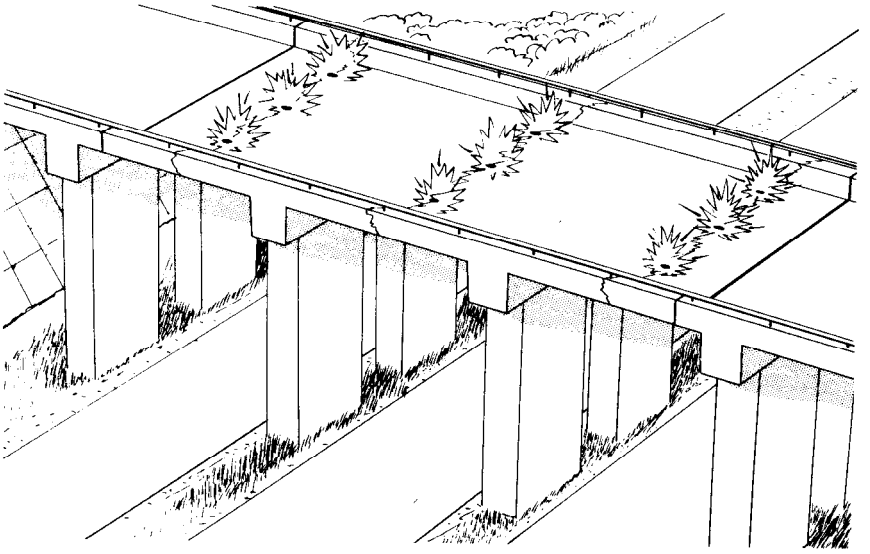


Figure 126. Placement of charge on conceret cantilever bridge without suspended span.

not containing a suspended span, the method shown in figure 132 is recommended. The top and bottom chords are cut at any desired point, and the bridge is cut through near the joint at the end of the arm in the same span. Another method of destruction is to cut completely through the bridge at any two points in the same span, thereby dropping out the length of bridge between the two cuts.

116. Arch Span Bridges

a. Components. A few of the components of bridge arches are described below and illustrated in figure 133.

(1) *Span.* The horizontal distance from one support of an arch to the other measured at the spring line.

(2) *Spring lines.* The points of junction between the arch and the supports.

(3) *Rise.* The vertical distance measured from the horizontal line connecting the supports to the highest point on the arch.

(4) *Crown.* The highest point on the arch.

(5) *Abutments.* The supports of the arch.

(6) *Haunches.* Those portions of the arch that lie between the crown and the spring lines.

(7) *Spandrels.* The triangular-shaped areas between the crown and abutment and above the haunches.

b. Filled Spandrel Arch. A filled spandrel arch consists of a barrel arch (comparatively short span) supporting an earth or rubble fill between the retaining walls. The arch is the most vulnerable at its crown, where it is the thinnest and the earth fill is usually only a foot or two thick. Filled spandrel arches are constructed of masonry (stone or brick), reinforced concrete, or a combination of these

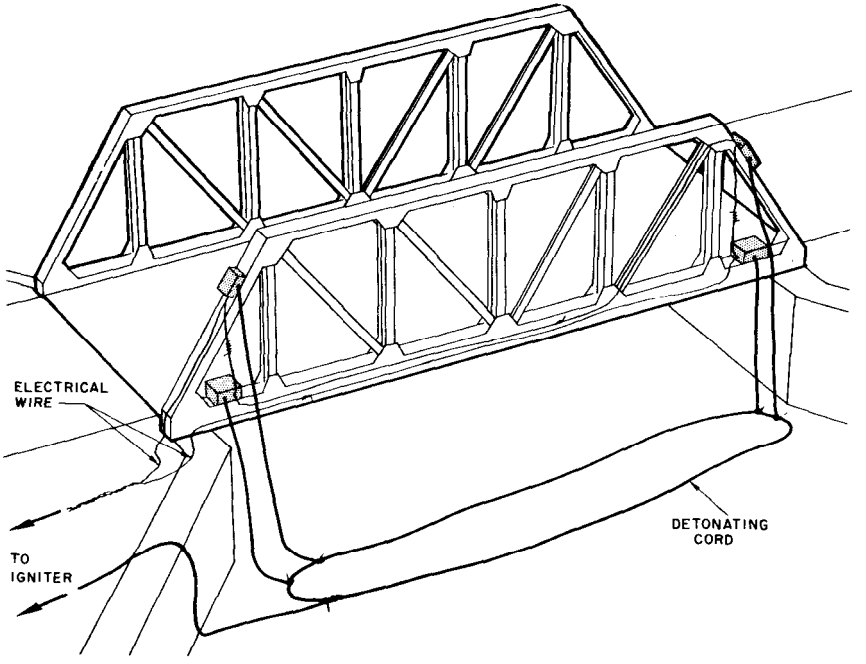


Figure 127. Bridge destruction aided by its own weight.

materials. They may be destroyed by either crown or haunch charges.

c. Demolition by Crown Charges. Crown charges are more easily and quickly placed than haunch charges; but their effectiveness is substantially less, particularly on an arch with a rise that is large in comparison with the span. Crown charges are more effective on the flatter arches because the flatter shape permits a broken portion of the arch to drop out of the bridge. Breaching charges are placed as shown in figure 134.

d. Demolition by Haunch Charges. Breaching charges may be placed at the haunches (just ahead of the abutment) as shown in figure 135 and the traffic maintained until they are fired. If the bridges have demolition vaults or chambers built into the haunches, the charges should be placed there. The presence of demolition vaults is usually revealed by the ventilating brick or steel plate laid in the side wall of the arch. Charges placed in the haunch on the left side will drop out that portion of the arch between lines C and D as shown in figure 135. Charges in both haunches will drop out that portion of the arch between lines C and E. The breaching charges must be placed on the arch ring either in holes on the top or supported on the under side.

117. Open Spandrel Arch Bridges

An open spandrel arch consists of a pair of arch ribs that support columns or bents which in turn support the roadway. The number of arch ribs may vary, and on rare occasions the spandrel bents may be placed on a full barrel

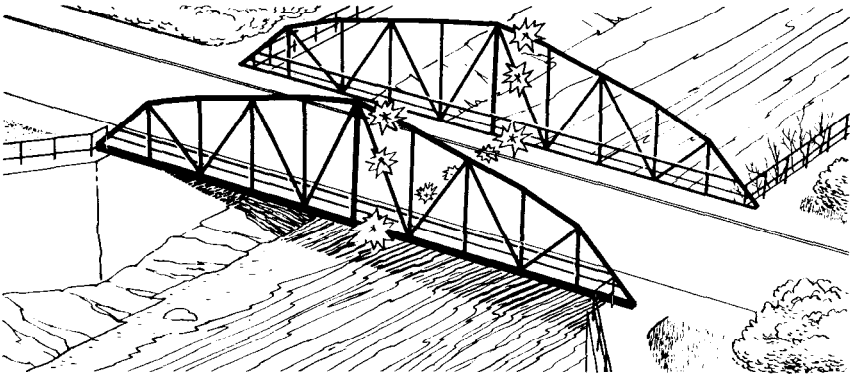


Figure 128. Placement of charge to cut diagonal and upper and lower chords.

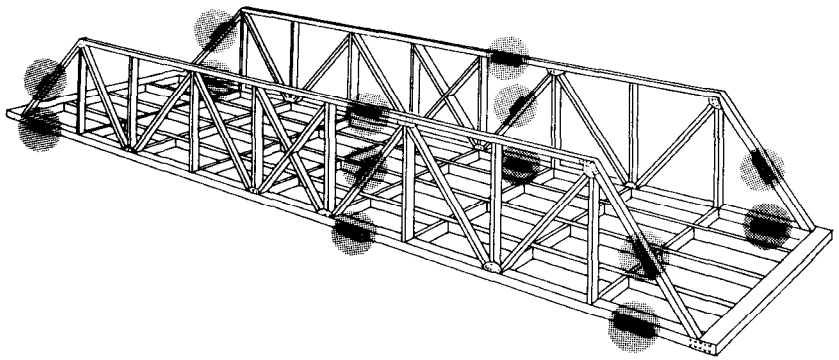


Figure 129. Placement of charges to cut trusses into segments.

arch similar to that which supports the filler material of the filled spandrel arch. The open spandrel arch bridge (fig. 136) may be constructed of reinforced concrete, steel, timber, or any combination of those materials.

a. Demolition of Concrete Open Spandrel Arch. The ribs of a concrete open spandrel arch bridge (fig. 136) are about 5 feet wide. The thickness of the arch rib at the crown varies from about 1 foot for spans of 50 to 60 feet in length to 3 feet for spans of 200 feet or more. The arch thickness at the spring line is ordinarily about twice the thickness at the crown. In long spans, the ribs may be hollow. The floor slab is usually close to the crown, permitting packing of charges against the rib at this point. Here again, the same difficulties are found in reaching the working points at the crown as in T-beam (para 112) or in stringer bridges (para 110). Since for struc-

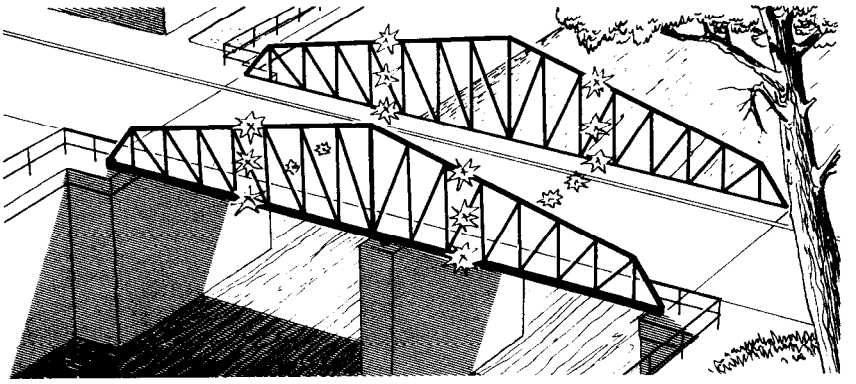


Figure 130. Demolition of a continuous span truss.

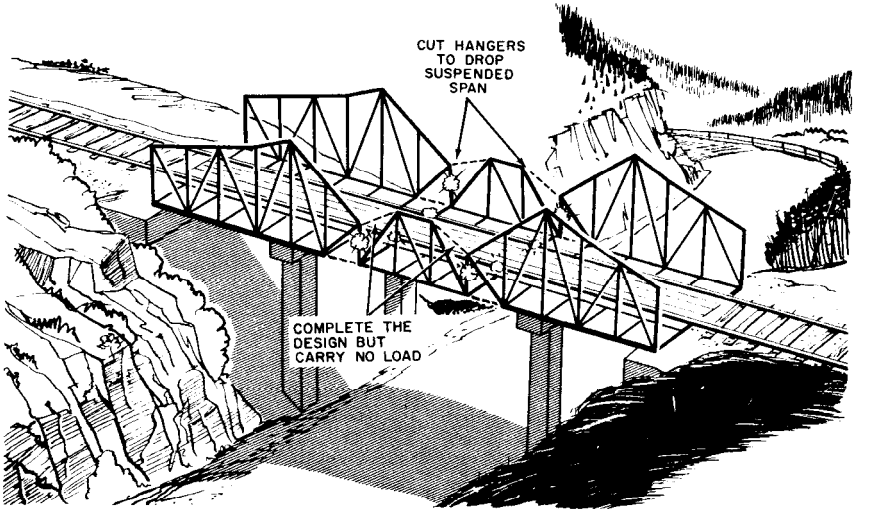


Figure 131. Demolition of cantilever truss with suspended span.

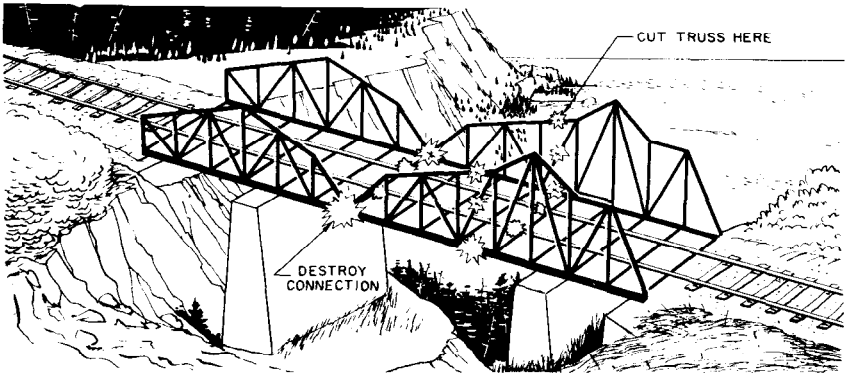


Figure 132. Demolition of cantilever truss without suspended span.

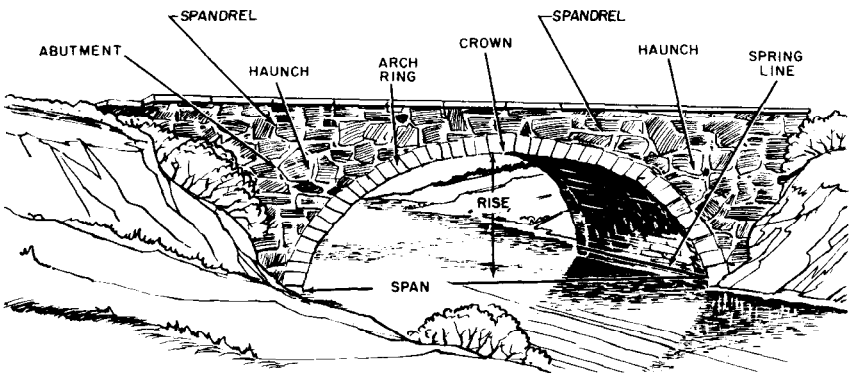


Figure 133. Arch components.

tural reasons, the haunch over the abutment is most likely to be heavy, effective destruction of the arch itself by means of light crown charges may leave a substantial pier at roadway level in an undamaged condition. This type of structure is usually built in one massive unit rather than in lighter separate component parts and is very tough. Also, cutting the span at each end may drop the whole span only a relatively short distance. This may make the damaged bridge an excellent support for building a new temporary bridge. Therefore to prevent utilization of such a span, one charge is placed at the haunch and another at the crown. The uncut half-span will then also fall if the total span exceeds 50 or 60 feet. The charge at the haunch is computed for placement at either the ring or the pillar over

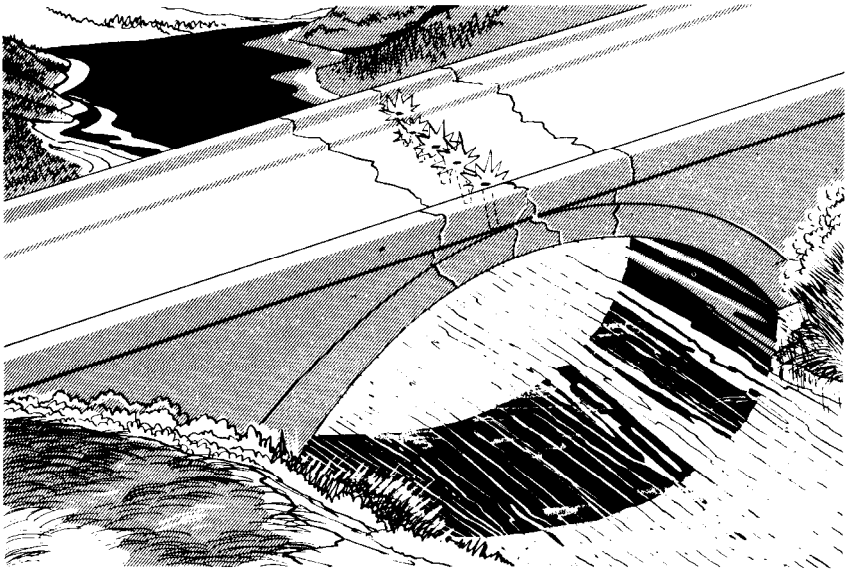


Figure 134. Breaching by crown charges on filled spandrel arch bridge.

the support, whichever has the greater radius. For short single arch spans, destroy the entire span with breaching charges laid behind the abutments or behind the haunches.

b. Demolition of Steel Arch Span. Steel arches are of four general types: continuous arches ((1) fig. 137), one-hinged arches (2), two-hinged arches (3), and three-hinged arches (4). One-hinged arches are hinged in the middle; two-hinged arches, at both ends; and three-hinged arches, at both ends and in the middle. Continuous arches and one-hinged arches are destroyed by placing charges at both ends of the span just far enough from the abutment to allow the arch to fall. Two-hinged and three-hinged arches need only one charge apiece for destruction. This should be placed at the center of the span.

118. Suspension Span Bridges

The suspension span bridge is usually a major bridge distinguished by two characteristics: the roadway is carried by a flexible member, usually a wire cable, and the spans are long (fig. 138).

a. Components.

(1) *Cables.* Cables of suspension bridges are usually two steel multi-wire members that pass over the tops of towers to anchorages on each bank. The cables are the load-carrying members. (The "Golden Gate" bridge has 127,000 miles of cable wire.)

(2) *Towers.* Towers of a suspension bridge support the cables or load-carrying members. They may be made of steel, concrete, masonry, or a combination of these materials.

(3) *Trusses or girders.* The trusses or girders of a suspension bridge do not support the load directly. They provide stiffening only.

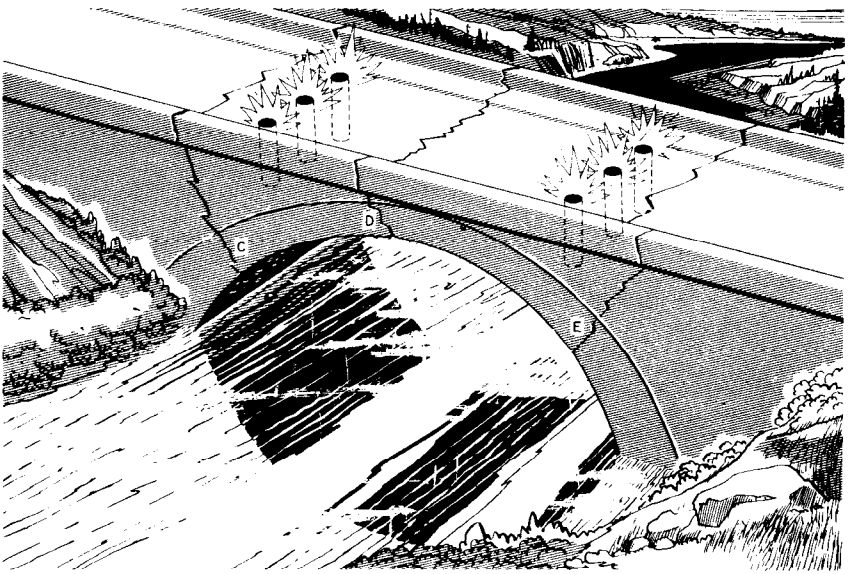


Figure 135. Breaching by haunch charges on filled spandrel arch bridge.

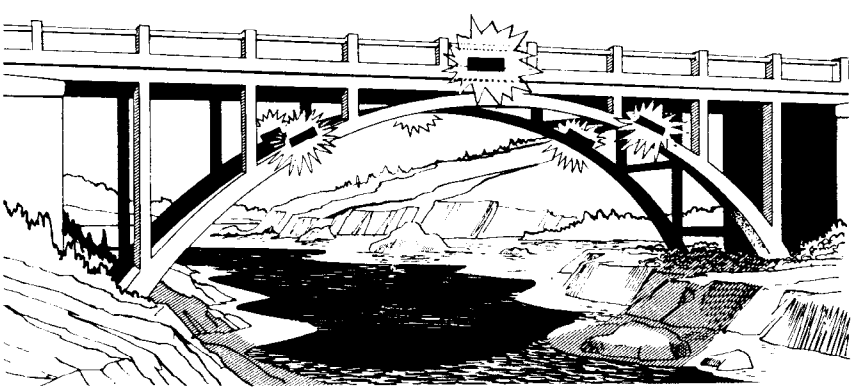


Figure 136. Demolition of reinforced concrete open spandrel arch bridge.

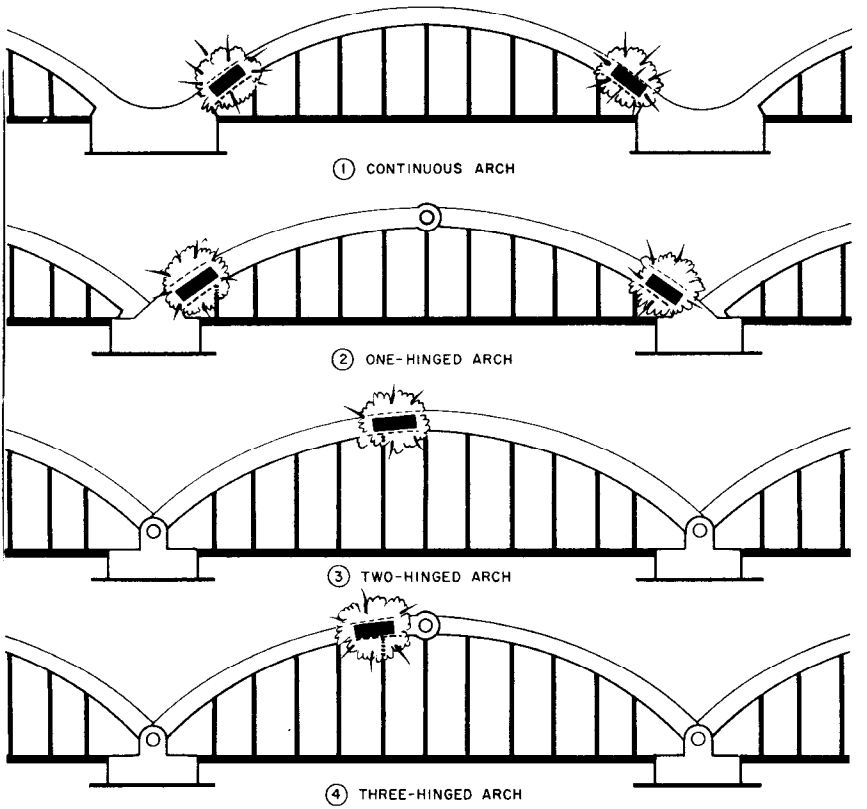


Figure 137. Demolition of steel arch bridges.

(4) *Anchorage.* The usual anchorage is merely the setting of the splayed end of the cable in a rock or a concrete mass. This may be large-sometimes as much as 1000 cubic feet in size.

b. Destruction.

(1) *Major structures.* The towers and anchorages of a major suspension bridge are usually too massive to be destroyed, and the cables are too thick for positive cutting with explosives. The most economical method of destruction is either by dropping the span leading onto the bridge or dropping a section of the roadway by cutting the suspenders of the main or load-bearing cables. The length of this section should be determined by an analysis of what capabilities the enemy has for repair in the time

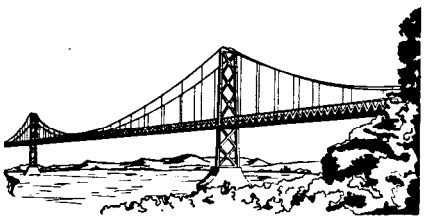


Figure 138. Suspension span bridge.

he is expected to retain the site, particularly the erection of a prefabricated bridge. It may also be feasible where there are reinforced concrete towers to breach off the concrete and cut the steel.

(2) *Minor structures.* The two vulnerable points of a minor suspension bridge are the tower and the cables.

(3) *Towers.* Charges may be placed on the towers slightly above the level of the roadway. A section should be cut out of each part of each tower. A charge is placed on each post to force the ends of the cutout section to move in opposite directions twisting the tower. This will prevent the ends of a single cut from remaining in contact. Demolition chambers, provided in some of the newer bridges, make blasting easier, quicker, and more effective.

(4) *Cables.* Charges should be placed on the cables as close as possible to firm support such as at the top of the tower or at an anchorage. Extreme care should be taken to extend the charges not more than one-half the distance around the circumference of the cable. These charges are bulky, exposed, and difficult to place; and the cables are difficult to cut because of the air space between the individual wires. Shaped charges, however, with their directed force effect, may be used to advantage.

119. Floating Bridges

Floating bridges consist of a continuous roadway of metal or wood supported by floats or pontons.

a. Pneumatic Floats. Pneumatic floats consist of rubberized fabric made into airtight compartments and inflated with air.

(1) *Hasty method of destruction.* The anchor cables and bridle lines may be cut with axes and the steel cable, by explosives.

(2) *Deliberate method of destruction.* The floats may be punctured by small arms or machinegun fire. This requires a considerable volume of fire because of the large number of watertight compartments in each float. Detonating cord stretched snugly across the surface of inflated ponton compartments will make a clean cut through the material. One strand will suffice to cut most fabrics; two may be required for heavier material. Also one turn of detonating cord around an inflation valve cuts it off at the neck or does other damage. Lines placed around valves should not be main lines but branch lines run off from the main line, as the blast wave may fail to continue past the sharp turn.

b. Rigid Pontons. Rigid pontons are made of various materials such as wood, plastic, or metal. Most of these are open but occasionally they are decked over.

(1) *Hasty method of destruction.* A ½-pound charge of explosive is placed on the upstream end of the bottom of each ponton and detonated simultaneously. If the current is rapid, another method is to cut the anchor cables so that the bridge will be carried downstream.

(2) *Deliberate method of destruction.* The bridge is severed into rafts and half-pound charges of explosives are placed at each end of each ponton and detonated simultaneously.

c. Treadways. Charges to destroy the treadway of any metal treadway type of floating bridge may be calculated by means of the steel-cutting formula. The placement and amount of the charges to be used depends on the type of bridge to be destroyed. In general, if charges

are set to sever the roadway completely at every other joint in the treadway, the bridge will be damaged beyond use.

120. Bailey Bridges

A 1-pound charge placed between the channels of the upper and lower chords will destroy the panels. A ½-pound charge will cut the diagonals and a 1-pound charge, the sway bracing (fig. 139).

a. Bridge in Place.

(1) The bridge is severed into parts by cutting panels on each side, including the sway braces. The line of cut is staggered through the panels; otherwise the top chords may jam and prevent the bridge from dropping. In double-story or triple-story bridges, the charges are increased on the chords at the story junction line.

(2) For further destruction, charges are placed on the transoms and the stringers.

b. Bridges in Storage or Stockpile. Destruction of bridges in storage must be such that the enemy cannot use any of them as a unit or any parts for normal or improvised construction. This requires that one essential component, not easily replaced or improvised, be destroyed so that the bridges at a particular stockpile cannot be used. In this way it will also be impossible for the enemy to obtain replacements for other sectors. The component that fulfills all of these conditions is the panel. To make the panel useless, the female lug in the lower tension cord is removed or distorted. All panels should be destroyed before other components are destroyed.

Section IV. DAMAGING TRANSPORTATION LINES

121. Highways

Disruption of enemy transportation lines is an important demolition objective. The extent of demolition, however, depends upon the analysis of the system and the mission. By the destruction of the road net, the attacking forces are halted or delayed, the movement of supplies is prevented, and frequently new construction is required before the enemy can advance. This may be accomplished by the demolition of bridges, by blowing road craters, by placing wrecked items of equipment and debris in cuts and defiles, and by the construction of abatis and roadblocks.

122. Railroads

a. Tracks.

(1) If possible, the destruction of railroads with explosives should be done at vulnerable points. These are curves, switches, frogs, and crossovers, which may be destroyed with a small amount of explosive. This is called the "spot" method. Placement of charges is shown in figure 140.

(2) A length of single track may be destroyed rapidly by a detail of soldiers with a push car, ¼-ton truck, or other vehicle supplied with explosives, nonelectric blasting caps, time fuse, fuse lighters, and filled sandbags. Several soldiers ride the vehicle, prime 1-pound charges, and hand them, together with sandbags, to men walking immediately behind the vehicle. These men place the charges against the rail on alternate connections of both tracks for a distance of about 500 feet, and then tamp them well with sandbags. Tamping is not required to break the rail, but will destroy a longer length of rail. Other men follow about 250 yards behind the vehicle to light the fuses. This method requires approximately 20 pounds of explosive per 500-foot length of single track line. It should be repeated at approximately 1½-mile intervals. Such procedure is particularly advantageous when the supply of explosives is limited or when time or other factors prohibit complete destruction of a line. It causes a greater delay in repair than a concentrated destruction of short lengths of track. If time, explosives and other conditions permit, however, complete

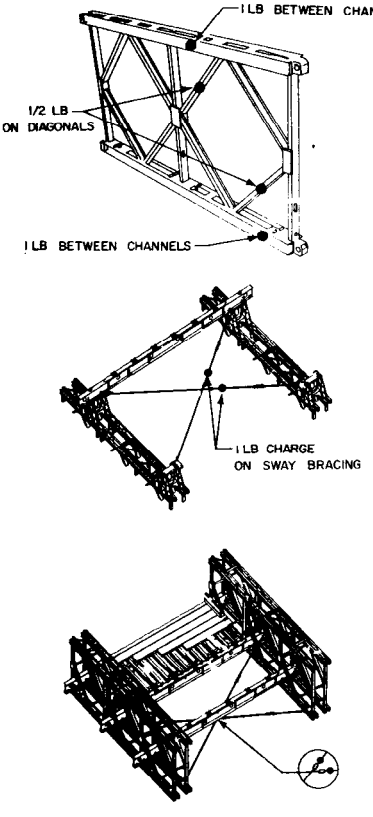


Figure 139. Demolition of Bailey bridge.

destruction of long lengths of track will provide maximum delay.

(3) Tracks may be made unserviceable without the use of explosives by tearing up sections of the track, especially along cuts, fills, or embankments, where the use of reconstruction equipment is restricted and work areas are limited. This may be done by removing fishplates from both ends of a section of track, fastening a heavy chain or cable to it, and pulling it up by a locomotive. Also, a large hook towed by a locomotive is useful to tear up ties and rails. Whenever possible, ties loosened from the rails should be piled and burned.

b. Roadbeds. Roadbeds are damaged by the methods used in making road craters and antitank ditches.

123. Tunnels

Railway and highway tunnels located on major routes to strategic industrial or military areas are vulnerable to demolition and therefore desirable targets. Tunnel demolition, however, with hastily placed conventional explosives is impossible unless huge quantities are used. But when demolition chambers exist or time, men, and equipment are available, considerable damage to tunnels can be accomplished with reasonable amounts of explosive.

a. Principal Factors in Tunnel Demolitions. The most critical factor in tunnel demolition is the tightness of the lining against solid rock. The actual thickness and strength of the lining are of secondary importance. The degree of contact of the walls with surrounding rock influences the amount of blast energy transmitted to the rock or retained in the concrete and the consequent movement of broken fragments, which may permit their being dislodged and dropped into the tunnel.

b. Hasty Demolitions. The hasty demolition of tunnels with reasonable amounts of conventional high explosives is ineffective. No hasty method has yet been devised that will cause extensive damage. The enemy may be temporarily deprived of the use of a tunnel by breaking and dislodging portions of the lining with normal breaching charges placed at a number of points and by creating slides at the tunnel portals by placing cratering charges in the slope above them. Nuclear devices of proper size advantageously placed, will effectively demolish a tunnel.

c. Deliberate Demolitions. Deliberate tunnel demolitions will produce satisfactory results when explosive charges are detonated in prepared chambers in the material adjacent to the inner face of the tunnel, whether it is lined or

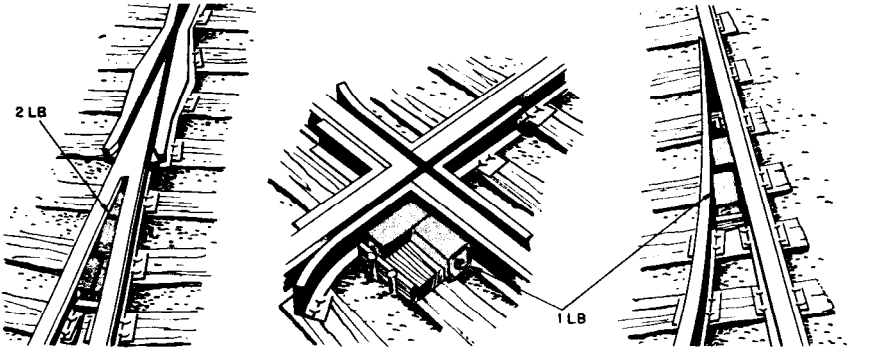


Figure 140. Demolition of railroad switches, frogs, and Crossovers.

not. Excessive charges are not required. Maximum damage desired in any tunnel is that of obstructing it with broken rock. Secondary damage by fire may also occur. Caving, which may result from structural damage to the tunnel arch, cannot be predicted. To obtain maximum damage to tunnels, the methods outlined below are adequate.

(1) *Charge chambers.* Tunnel charge chambers should be so constructed that each chamber parallels the long axis of the tunnel at or above the spring line. The T-design tunnel charge chamber is an efficient means of inflicting serious damage. The chambers may be constructed opposite each other at staggered intervals on opposite sides, or all on one side of the tunnel. The maximum burden, which is the distance from the charge to the inside rock wall, should be 15 feet. The tunnel charge chamber should be no larger than necessary for convenience of construction and loading and no smaller than 3 feet wide by 4½ feet high. Charge chambers should be constructed far enough inside the tunnel portal to insure confinement of the charge. The minimum of side hill or outside burden should be 30 feet.

(2) *Charges.* Seven hundred and fifty pounds of high explosive is an effective minimum charge for single placement within a T-type chamber of 15-foot burden. Charges should be placed on 30-foot centers.

(3) *Stemming.* Stemming, the material with which a borehole or charge chamber is filled or tamped (usually earth-filled sandbags), is necessary. It should extend from the last charge in the T-type chamber to the chamber entrance. Stemming is not necessary, however, between charges within the chamber.

d. Deliberate Demolition of Tunnels With Prepared Charge Chambers. Some tunnels have chambers or holes in the roof for the purpose of demolishing them at some future time. Their presence is usually indicated by the open brick ventilators placed over them. If no ventilators are present, these chambers may be located by striking the roof of the tunnel with some heavy metallic object, which usually produces a hollow sound. Explosives, compacted as tightly as possible, are placed in the chambers, which are then closed and sealed except for the place where the fuze or firing wire passes through. Sandbag stemming is recommended in all charge chambers in timbered tunnels, as the sandbags increase the possibility that the timbers may ignite when the charge is detonated.

124. Water Transportation Systems

The extent of demolition depends largely upon the mission, materials available, and an analysis of the system as to how critical, accessible, repairable, and vulnerable it may be.

a. Vessels, Piers, and Warehouses. Vessels can seldom be destroyed efficiently by landbased troops, unless they are tied up at docks, piers, and warehouses, however, are excellent demolition targets, especially for the use of fire.

b. Channels. The most expeditious way to block a channel is to sink a ship or a loaded barge at a point that cannot be bypassed. Channels with retaining walls may be blocked effectively by detonating breaching charges behind the retaining walls.

c. Dams. Since a prohibitive amount of explosive is generally required to destroy an entire dam structure, the best and quickest method is to destroy the machinery and the equipment. If the purpose of the demolition is to release the water in the dam, all that is required is to destroy the gates on the crest of the dam, the penstocks or tunnels used to bypass the dam or to carry water to hydroelectric plants, or the valves or gates used to control the flow in the penstocks or tunnels. In dams, partly or wholly constructed of earth fill, it may be possible to ditch or crater down below the existing waterline and thus allow the water itself to further erode and destroy the dam. Nuclear devices may also be used to advantage.

d. Canals. In most cases, a canal may be made useless by destroying the lock gates and the operating mechanism that controls them. This mechanism, which includes the electrical equipment and perhaps pumps, is the easier to destroy and should therefore be attacked first. If time permits, the gates themselves may be destroyed. The lock walls and canal walls may be destroyed by breaching charges or cratering charges placed behind them.

125. Airfields

Airfields may be destroyed by ADM. They may be rendered unusable by cratering runways or placing objects on surfaces to prevent use by aircraft. The destruction of POL and munitions stocks and of repair and communications facilities is also effective. Rooters, plows, and bulldozers can ditch runways that are not constructed of concrete. Friendly operational and nonoperational airfields should be destroyed only in areas where the resulting wreckage will provide the maximum impediment to enemy movement and operations. They should, however, be made ready for demolition only during the preparation for an organized withdrawal when seizure by the enemy is imminent.

a. Plans for Demolition.

(1) The methods of destroying any airfield depend on the materials at hand, the type of installation to be destroyed, and the time and equipment available to complete the job. Aircraft and equipment may be destroyed instantly by directing weapons fire against them. Whenever possible, bombs and ammunition should be used as explosive charges (app C). Gasoline and other fuels (POL products) may be used to aid in the destruction, by fire, of vehicles, equipment, and buildings.

(2) When time permits, a detailed plan for demolition of the airfield should be prepared before any charges are placed. This should include—

(*a*) Location of charges.
(*b*) Type of explosives.
(*c*) Size of each charge.
(*d*) Priority in preparation and placement of each charge.
(*e*) Total amount of itemized explosives and other materials needed to effect demolitions included in the plan.
(*f*) Assignment of personnel or groups to prepare specific charges.

b. Priorities for Demolition. It is seldom possible to destroy an airfield completely because of the great amount of explosives and time required. Thus it is necessary to determine what specific demolition is to be done and in what order specific operations are to be accomplished. Airfield demolition plans should be very flexible, particularly in regard to priorities. The order of priority should vary according to the tactical situation. The following list suggests an order of priority for airfield demolition, which may be modified to suit the tactical situation.

(1) Runways and taxiways and other landing areas.
(2) Routes of communication.
(3) Construction equipment.
(4) Technical buildings.
(5) Supplies of gasoline, oil, and bombs.
(6) Motor vehicles and unserviceable aircraft.
(7) Housing facilities.

c. Runways and Taxiways. Runways and taxiways have first priority in a demolition plan because the destruction of landing surfaces is the most important single item. Whenever possible, demolition of an airfield should be considered during construction by the placing of large conduits in all fills. This requires little extra work and provides a means of placing explosives under the runway. Standard deliberate and hasty craters may be useful in the demolition of runways and taxiways. Shaped charges may be used to breach thick concrete pavement when speed is essential. The placing of individual cratering charges diagonally down the runways or taxiways, or in a zigzag line running diagonally back and forth, provides more complete destruction. When pierced steel plank or other type of landing mat is used on an airfield, substantial damage may be done by attaching a large hook to sections of the mat and pulling it out of place with a tractor. This should be followed by cratering. A hasty, satisfactory obstacle may be produced by the use of 40-pound cratering charges spaced every 15 feet across the runway and buried 4 feet under the ground.

d. Turf Surfaces and Pavements. Bituminous surface treatments or thin concrete pavements can be destroyed by bulldozers, graders, and rooters. Turf airstrips can be destroyed by plowing or cratering.

e. Aircraft. Unserviceable aircraft should be destroyed by the detonation of 4 pounds of TNT placed on each crankshaft between the propeller and the engine and 1 pound of TNT placed on the instrument panel to prevent salvage. The engines of jet-propelled aircraft should be destroyed by detonating charges on essential parts, such as the compressor, air intake, or the exhaust turbine. Radio equipment, bombsights, radar, and tires should be removed or destroyed.

126. Pipelines

The most vulnerable points of a pipeline system are the storage tanks and pumping stations.

a. Storage Tanks. Storage tanks filled with fuel may be destroyed most effectively by burning with incendiary grenades or the burst of .50-caliber incendiary ammunition. Empty tanks may be destroyed by detonating charges against the base.

b. Pumping Stations. Booster pumping stations on cross-country pipelines, being very vulnerable, should be destroyed. Gravel or other solid objects introduced into the pipeline while the pumps are running will damage the moving parts, although not to the degree possible with explosives. If time permits, the pumping station should be burned after the equipment has been destroyed by explosives.

c. Pipe. The pipe used in pipelines is destroyed only during scorched earth operations because of the great amount of effort necessary for effective damage. Junctions, valves, and bends are the most suitable points, particularly when the line is buried. Another method is to close all valves on the line; the expansion that occurs, even in subzero weather, will break it.

Section V. DAMAGING COMMUNICATION SYSTEMS

127. Telephone and Telegraph Lines

Although damage to an enemy telephone system or telegraph system may never be extensive, it does have a great delaying effect. Telephone and telegraph switchboards and instruments are the best points of attack. Generally 1-pound charges placed on the cables are adequate to sever them. Also dial systems may be damaged by smoke from burning oil. Pole lines are not satisfactory targets as they are strung over long distances and can be destroyed only in spots. They may be made temporarily useless by cutting or grounding the wires or by cutting the poles with small external timber-cutting charges and then burning. The wire should be cut into short lengths to prevent further use.

128. Radio Installations

Radio provides rapid communication between far distant points that would otherwise be without communication. Antenna towers, usually constructed of steel and braced with guy wires, are the most accessible part of any radio installation. They are destroyed by cutting the guy wires and by placing cutting charges against the base. The towers should be toppled over the transmitter station or across the high voltage transmission line through which the installation received its power. Equipment and standby power units may be destroyed by mechanical means or by demolition charges. Transformers also are very vulnerable. They will burn themselves up if a hole is blasted in the side or bottom and the oil let out, provided they do not have automatic thermo cutoff switches.

Section VI. DESTRUCTION OF BUILDINGS AND INSTALLATIONS

129. Buildings

Buildings may be destroyed by explosive or other methods. The methods used and the extent of demolition usually depend on the time available.

a. Masonry or Concrete Buildings. Masonry or concrete buildings may be destroyed by breaching charges placed on the inside and at the base of the exterior walls.

b. Wood or Thin-Walled Buildings. Wooden frame buildings may readily be destroyed by fire. Another method is to close all doors and windows and explode on the ground floor a concentrated charge (dust initiator) equal to ¼ pound to 1 pound of explosive per cubic yard of volume (app F). Such buildings may be dismantled, however, if time permits.

c. Steel Framed Buildings. Stink bombs and other malodorous devices and contaminants may be all that is required to damage the interior furnishings or equipment. Another method—to expose the interior to extreme heat, 1000° F for 10 minutes—will cause failure of the structural steel members. Buildings with steel frames may also be destroyed by first breaching the concrete or masonry where necessary to expose the vital steel members and then cutting them with explosive charges.

d. Concrete Beam, Curtain Wall Buildings. Concrete beam curtain wall buildings, constructed in such a way that the load is carried by reinforced concrete beams and columns, are destroyed by placing breaching charges inside the buildings at the base of the exterior wall and at the base of all intermediate columns on the ground floor.

130. Electric Power Plants

Before destruction, electric power plants should be studied so that the amount of damage will be adequate but not exceed tactical demands. They may be destroyed by cutting the windings of generators and motors, by placing and detonating a 2-pound charge inside the casings, or by pouring gasoline on the generators and lighting them. Generators also may be "shorted" out by the use of metal powder or shavings. The shafts of motors and generators are broken. Damage can also be done by removing or contaminating the lubricating oil with metal filings or aluminum powder and then running the machinery. Boilers are burst with a cutting charge. All buildings, transmission towers, penstocks, and turbines of hydroelectric plants may be destroyed.

131. Water Supply

The pumping station, filtration plant, and reservoirs of a water supply system are usually the points most accessible to attack. Storage tanks are demolished by charges calculated on the basis of 1 pound of explosive per 100-cubic foot capacity. The charge is detonated inside the tank when it is full of water. The water acts as a tamping material. Shaped charges are also useful in this capacity. The standoff, however, should be cut down considerably. Wells sunk in soft soils are damaged beyond repair by charges that cut the lining. Wells in rock and hard soils, having little or no lining, are demolished by exploding large breaching charges 6 to 12 feet from the edge of the well and deep enough to secure good tamping. If time does not permit such preparation, a large charge is exploded halfway down against the side.

132. Petroleum, Oil, and Lubricating Refineries

POL refineries are readily demolished, hav-

ing such extremely vulnerable points as cracking towers, steam plants, cooling towers, and POL stock. These are easily damaged by explosive charges and fire. The demolition of such installations should be planned and executed only by persons familiar with their design and construction or after extensive investigation.

Section VII. DESTRUCTION OF EQUIPMENT AND SUPPLIES

133. Introduction

a. Authority for Destruction. The destruction of friendly materials is a command decision, implemented only on authority of the division or higher commander. Equipment and supplies that cannot be evacuated and may, therefore, be captured by the enemy are destroyed or made unserviceable, except for medical materials and stores, which are not to be intentionally destroyed (DA Pam 27–1 and FM 8–10).

b. Destruction Areas. Whenever possible, mobile equipment is demolished in places where it most effectively impedes the advance of the enemy. Examples of such places are—

(1) Approaches to bridges (fills).
(2) Airfield landing strips.
(3) Cuts, fills, or hills on roads.
(4) Sharp bends of roads.
(5) Roads leading through densely wooded areas.
(6) Narrow streets in thickly populated or built-up areas.

c. Priority of Operations. Destruction must be as complete as the available time, equipment, and personnel will permit. If all parts of the equipment cannot be completely destroyed, the most important ones should be damaged. Special attention must be given to those parts that are not easy to duplicate or rebuild. Particular care must be taken that the same components are destroyed on each piece of equipment; otherwise the enemy may assemble a complete unit with parts taken from several partly destroyed units (cannibalization).

d. Precautions. When material is destroyed by explosives or by weapons fire, flying fragments and ricocheting bullets create a hazard. Thus demolition must be accomplished in an area free of friendly troop concentrations.

134. Planning

Standing operating procedures for all units should contain a plan for the destruction of all equipment and supplies except medical supplies, which are left intact for enemy capture. Such a plan will insure that the maximum and most effective damage is done to materiel and will deny the use of friendly equipment to the enemy. It should outline the required extent of demolition and include priorities of demolition and methods of destruction for all items issued to the unit. If explosives are to be used, the amounts required should be indicated. The plan must be flexible enough in its designation of time, equipment, and personnel to meet any situation. In order to make cannibalization by the enemy impossible, each equipment operator must be familiar with the priority sequence in which essential parts, including extra repair parts, are to be destroyed. He must also be familiar with the sequence to be followed for total destruction.

135. Methods of Destroying Material

The following methods of destroying material may be used either singly or in combination. The actual method or methods used in a given situation depend on the time, personnel, and means available.

a. Explosives. All military explosives are effective in destroying equipment.

b. Mechanical Means. Material may be destroyed by mechanical means. Sledge hammers, crowbars, picks, axes, and any other available heavy tools are used to smash or damage whatever is to be destroyed.

c. Weapons Fire. Hand grenades, rifle grenades, antitank rockets, machinegun fire, and rifle fire are a valuable means of destroying materiel.

d. Thermite Grenades. Flammable material and equipment may be destroyed or made unserviceable by heat generated by the thermite

grenade. The material should be soaked with fuel before burning.

e. Fire. Rags, clothing, or canvas should be packed under and around the materiel to be destroyed. It should then be soaked with gasoline, oil, or diesel fuel. Damage from fire may not always be as severe as expected. Engine or transmission parts heated to less than a dull red heat are not seriously damaged provided they are lubricated immediately after the fire to prevent corrosion. Electrical equipment, including motor or generator armature windings and other wiring, is effectively destroyed by burning. All parts made from low-melting-point metal may be almost completely destroyed by fire.

f. Water. The damage resulting from submerging equipment in water is not generally very severe, but the method is sometimes rather quickly and easily accomplished. Total submersion also provides concealment of equipment (*h* below).

g. Abuse. Much damage can be done to equipment, particularly to engines, by deliberate improper operation. Such abusive treatment may proceed even after abandonment, if hasty action becomes necessary, by leaving the equipment in an improper operating condition.

h. Concealment. Easily accessible vital component parts of equipment may be removed and scattered through dense foilage, thus preventing or at least delaying use by the enemy. Vital parts of entire items may be hidden by throwing them into a lake, stream, or other body of water (*f* above).

i. Boobytrapping. Boobytraps are placed in debris after destruction is completed, if time permits. See FM 5–31 for the techniques.

136. Destruction of Combat Equipment

There are various publications on the proper methods of destroying military combat equipment. The FM 23-series is concerned with the destruction of small arms such as rifles, pistols, mortars, and ammunition; and the FM 17-series, with the destruction of armored vehicles and their weapons.

137. Training

Training does not involve the actual demolition of any materiel but the simulated breaking of vital parts, the placing of dummy charges, and the selection of sites suitable for the destruction of equipment in order to block communication routes. Drivers and operators should be made familiar with each step in the appropriate method for the destruction of their equipment and supplies. It should be emphasized that in planning destruction operations, the following methods should be considered in the order given:

a. Mechanical damage to vital parts.

b. Use of explosives.

c. Use of weapons fire, fire, and water.

CHAPTER 5

SAFE HANDLING, TRANSPORTATION, AND STORAGE OF EXPLOSIVES

Section I. GENERAL SAFETY PRECAUTIONS

138. Safety Rules and Responsibility

a. Compliance. Safety rules regarding explosives, caps, and demolition equipment will be followed strictly during training. In combat, however, some must of necessity be altered so that unit missions may be accomplished. In all other situations they will be observed to the fullest extent permitted by time, materials available, and requirements of the mission. Also, post regulations and local and units SOP's will be observed.

b. Responsibility. The responsibility of the preparation, placement, or firing of charges must not be divided. One individual should be responsible for the supervision of all phases of the demolition mission.

139. Safe Distance Formula

Distances at which persons in the open are safe from missile hazards from bare charges placed on or in the ground are given in table XIV. The formula for computing safe distances from explosives so placed is—Safe distance in feet = 300 $\sqrt[3]{\text{pounds of explosives}}$. (For quarrying the safe distance in feet = 350 $\sqrt[3]{\text{pounds of explosives}}$). The minimum safe distance for soldiers in a missile-proof shelter is 300 feet (AR 385–63).

Table XIV. Minimum safe distances from explosives for persons in the open

Pounds of explosive	Safe distance in feet	Pounds of explosive	Safe distance in feet
1–27	900	150	1,593
28	909	175	1,678
29	921	200	1,754
30	930	225	1,825
32	951	250	1,890
34	969	275	1,951
36	990	300	2,008
38	1,008	325	2,063
40	1,020	350	2,114
42	1,041	375	2,163
44	1,050	400	2,210
46	1,074	425	2,256
48	1,080	450	2,299
50	1,104	475	2,341
55	1,141	500	2,381
60	1,170	525	2,420
65	1,200	550	2,458
70	1,230	575	2,495
75	1,260	600	2,530
80	1,290	625	2,565
85	1,317	650	2,599
90	1,344	675	2,632
95	1,368	700	2,664
100	1,392	725	2,695
125	1,500	750	2,725

Table XIV.—Continued

Pounds of explosive	Safe distance in feet
775	2,756
800	2,785
825	2,814
850	2,842
875	2,869
900	2,896
925	2,923
950	2,949
975	2,975
1000	3,000

Note. Chart is based on formula:

$$d = 300\sqrt[3]{P}.$$

d = safe distance in feet
p = pounds of explosive

140. Package Care and Repair

Carelessness, rough handling, and disregard for safety rules cause premature explosions, misfires, and in many cases serious accidents. Issued explosives and auxiliary items are packed in moisture-resistant containers and proper packing boxes to withstand field conditions of transportation and storage. Containers and boxes must never be handled roughly; they must never be broken, cracked, or dented. Some special items, if distorted, lose part of their effectiveness. Damaged packing boxes and containers must be repaired immediately; all defaced parts of marking must be transferred to new parts of the boxes. Broken airtight containers, such as those containing chemical mines, should be destroyed.

Section II. TRANSPORTATION, STORAGE, AND DISPOSAL

141. Transportation

a. Safety Policy. Local transportation of explosives for immediate use is directed by AR 385–63. The Department of the Army clearly defines the safety responsibilities of transportation officers at their installations. Local safety SOP's are provided to insure that all persons participating in the transportation of explosives have proper instruction in safety requirements and are held to account for all violations of procedure.

b. General Rules. The following rules are observed:

(1) Vehicles used for the transportation of explosives shall not be loaded beyond rated capacity and the explosives shall be secured to prevent shifting of load or dislodgement from the vehicle in transit. In all open-body types of vehicles the explosives shall be covered with a fire-resistant tarpaulin.

(2) All vehicles transporting explosives shall be marked with reflectorized placards on both sides and ends with the word EXPLOSIVES printed on.

(3) Blasting caps or other initiators shall not be transported in the same vehicle with other explosives, if possible; otherwise the caps should be carried in the front and the explosives in the rear of the truck.

(4) All vehicles used for transportation of explosives shall be in charge of, and operated by, a person who is mature-minded, physically fit, careful, reliable, able to read and write the English language, and not addicted to the use of intoxicants or narcotics. He should be aware of the destructive effects of explosives.

(5) No metal tools, carbides, oils, matches, firearms, electric storage batteries, flammable substances, acids, or oxidizing or corrosive compounds shall be carried in the bed or body of any vehicle transporting explosives.

(6) Vehicles to be used in the transportation of explosives shall be in good repair. When steel or part steel bodies are used, fire-resistant and nonsparking cushioning materials shall be employed to separate the containers of explosives from the metal.

(7) Vehicles transporting explosives shall be equipped with not less than two fire extinguishers placed at strategic points, filled and ready for immediate use, and of a make approved by the National Board of Fire Underwriters for class B and C fires.

(8) A vehicle containing explosives shall not be taken into a public building or repair shop or parked in congested areas for any period of time.

(9) All vehicles shall be checked before

transporting explosives and all electric wiring completely protected and securely fastened to prevent short circuiting.

(10) Vehicles transporting explosives shall be operated with extreme care and shall not be driven at a speed greater than 35 miles per hour. Full stops shall be made at approaches to all railroad crossings and main highways, and the vehicle shall not proceed until it is known that the way is clear. This, however, does not apply to convoys or protected crossings manned by highway flagmen or guards.

(11) All vehicles transporting explosives on public highways, roads, or streets shall have an authorized driver and helper. No person other than the authorized driver and helper shall be permitted to ride on trucks transporting explosives or detonators.

142. Magazines

a. Types. Explosives are stored in magazines according to the safety regulations prescribed in TM 9–1903. Table XV indicates the minimum distance for the location of magazines from other magazines, buildings, and routes of communication based on the quantity of explosives stored. There are two types of magazines—permanent and temporary. Although the permanent type is preferred, temporary or emergency types are frequently required when permanent construction is not possible.

b. Barricades. Explosives storage magazines must be barricaded, that is, have a substantial obstacle between them and inhabited buildings. For certain explosives, effective natural or artificial barricades reduce by one-half the distance necessary between magazines, railways, and highways. The use of barricades thus permits the storage of larger quantities of explosives in any given area. Although barricades help protect magazines against explosives and bomb or shell fragments, they are no safeguard against pressure damage.

c. Other Considerations. Magazines are usually placed at locations determined according to safety, accessibility, dryness, and drainage. Safety and accessibility, however, are the most important. An ideal location is a hilly area where the height of the ground above the magazine provides a natural wall or barrier to buildings, centers of communication, and other magazines in the area. Sidehill dugouts are not desirable, as adequate ventilation and drainage are often hard to provide. Brush and tall grass should be cleared from the site to minimize the danger of fire.

Table XV. Magazine Locations (Unbarricaded)

Qantity, pounds of explosives (not over)	Minimum distance in feet from nearest—		
	Inhabited building	Magazine	Public highway, railway, and/or electric lines
50	300	50	180
100	380	50	230
2,000	1010	140	610
20,000	1950	300	1170
100,000	3630	510	2180
225,000	4190	670	2515

Note. For more detailed information see TM 9–1903, C 1, 26 February 1957.

d. Lightning Protection. All magazines must have a grounded overhead lightning rod system. Also, all metal parts—doors, ventilators, window sashes, and reinforcing steel—must be connected in several places to buried conduits of copper-plate or graphite rods.

143. Field Expedient Structures

a. Field expedients for the storage of explosives when magazine construction is not possible are—

(1) A dugout excavated in a dry area and revetted with timber to prevent caving.

(2) An isolated building.

(3) A light wooden frame box house, with a wedge type roof covered by corrugated iron, or merely covered with a tent or canvas tarpaulin. The explosives should be placed on pallets for all-around ventilation.

b. Field expedient storage facilities should be appropriately marked by signs on all four sides, and guarded.

144. Temporary Magazines and Storage

Limited supplies of explosives can be stored for several days when necessary in covered ammunition shelters and should be so separated that fire or explosion cannot be transmitted from one shelter to another. Piles of explosives temporarily stored in the open should contain no more than 500 pounds, and be placed no less than 140 feet apart. Explosive components should be piled separately. Explosives, caps, and other demolition material stored temporarily in training areas should be kept separate in covered ammunition shelters, and under guard at all times. Temporary storage operations should be guided by local safety SOP's and other regulations (AR 385–63).

145. Destruction and Disposal of Explosives

a. Methods. Explosives, being insoluble in water, generally cannot be disposed of as sewage. Submergence, burning, or decomposition by chemical agents is necessary. Explosive material may be disposed of without alteration in form by dumping at sea. The best method of destroying explosives, however, is by burning.

b. Ordnance Units. Explosives are destroyed by explosive ordnance disposal units as directed in AR 75–15, TM 9–1385–9, TM 9–1900, TM 9–1903, and TM 9–1375–200.

APPENDIX A

REFERENCES

DA Pam 27–1	Treaties Covering Land Warfare.
AR 75–15	Responsibilities and Procedures for Explosive Ordnance Disposal.
AR 385–63	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
SM 9–5–1375	Stock List of Current Issue Items–FSC Group 13 Ammunition and Explosives, Class 1375 Solid Propellants, and Explosive Devices.
FM 5–15	Field Fortifications.
FM 5–26	Employment of Atomic Demolition Munitions (ADM).
FM 5–29	Passage of Mass Obstacles.
FM 5–31	Boobytraps.
FM 5–34	Engineer Field Data.
FM 5–35	Engineer's Reference and Logistical Data.
FM 8–10	Medical Service, Theater of Operations.
FM 19–30	Physical Security.
FM 20–32	Land Mine Warfare.
FM 20–33	Combat Flame Operations.
FM 23–30	Grenades and Pyrotechnics.
FM 31–10	Barriers and Denial Operations.
FM 101–31–1	Staff Officer's Field Manual; Nuclear Weapons Employment.
TM 5–220	Passage of Obstacles Other than Minefields.
TM 5–280	Foreign Mine Warfare Equipment.
(C) TM 5–280A	Foreign Mine Warefare Equipment (U).
TM 5–332	Pits and Quarries.
TM 9–1300–206	Care, Handling, Preservation, and Destruction of Ammunition.
TM 9–1345–200	Land Mines.
TM 9–1375–200	Demolition Materials.
TM 9–1375–203–12	Operator and Organizational Maintenance Manual: 10-Cap Capacity Handle Operated Blasting Machine.
TM 9–1385–9	Explosive Ordnance Reconnaissance.
TM 9–1900	Ammunition, General.
TM 9–1903	Care, Handling, Preservation, and Destruction of Ammunition.
TM 9–1910	Military Explosives.
GTA 5–10–9	Demolition Card.

APPENDIX B

METRIC CHARGE CALCULATIONS

1. Introduction

The following metric equivalent charge calculation formulas are included because of NATO requirements, wherein the United States and British Armies are gradually changing over from their tables of measurement to the metric system. Problems, solutions, and tables with measurements converted to the metric system are given below.

2. Structural Steel Cutting Formula

Formula: $K = \frac{A}{38}$

K = kilograms of TNT required

A = gross sectional area in square centimeters

Example: (fig. 97)

Flange Area = $2 \times 1.2 \times 12.7 = 30.48$ or 30.5 sq cm

Web Area = $28 \times 1 = 28$ sq cm

A (total) = 30.5 sq cm + 28 sq cm = 58.5 sq cm

$K = \frac{A}{38} = \frac{58}{38}$

K = 1.5 (use 1.5 kilograms of TNT)

3. Timber Cutting Formula

a. External Charge.

Formula: $K = \frac{D^3}{550}$

K = kilograms of TNT required

D = diameter of target in centimeters

Example: the diameter of a tree is 30 centimeters.

$K = \frac{30^3}{550} = \frac{900}{550}$

K = 1.64 kg

Use of 1.6 kilograms of TNT

b. Internal Charge.

Formula: $K = \frac{D^3}{3500}$

K = kilograms of TNT required

D = diameter of target in centimeters

Example: (fig. 96)

$K = \frac{D^3}{3500}$

$K = \frac{30^3}{3500} = \frac{900}{3500}$

K = .257 kg

Use 260 grams of TNT or any other explosive

4. Breaching Formula

Formula: $K = 16R^3KC$

K = kilograms of TNT required.

R = breaching radius in meters.

K = the material factor based on strength and hardness of material to be demolished.

C = the amping factor based on type and extent of tamping to be used.

Add 10 percent to calculated charge less than 22.5 kilograms.

For walls 30 centimeters (approx 1 ft) thick or less, increase the charge by 50 percent.

Table XVI. Value of Material Factor K for Calculation of Breaching Charges (Metric)

Material	Breaching radius	K
Ordinary earth	All values	0.05
Poor masonry, shale and hardpan, good timber, and earth construction	All values	0.23

Material	Breaching radius	K
Good masonry, ordinary concrete, rock	Less than 1 meter	0.35
	1 to less than 1.5 meters	.28
	1.5 to less than 2 meters	.25
	More than 2 meters	.23
Dense concrete, first-class masonry	Less than 1 meter	0.45
	1 to less than 1.5 meters	.38
	1.5 to less than 2 meters	.33
	2 or more meters	.28
Reinforced concrete (will not cut steel reinforcing)	Less than 1 meter	0.70
	1 to less than 1.5 meters	.55
	1.5 to less than 2 meters	.50
	2 or more meters	.43

a. Breaching Radius. The breaching radius (R) is the distance in meters which an explosive charge must penetrate and within which all material is displaced or destroyed. For example, to breach a 2-meter concrete wall by placing a charge on one side, the value of R in the formula $K = 16\ R^3KC$ is 2 meters.

b. Material Factor. The values of the material factor for various types of construction are given in table XVI.

c. Tamping Factor. The value of the tamping factor depends on the location and the tamping of the charge. No charge is considered fully tamped unless it is covered to a depth equal to the breaching radius. If underwater demolition is necessary, the tamping factor for placement of charges tamped with earth is used (fig. 105).

Example: Determine the amount of TNT required to breach a dense concrete pier 1.5 meters thick with untamped charges placed on the ground.

$R = 1.5$ meters

$K = .33$ (dense concrete, table XVI)

$C = 4.5$ (untamped, on the ground, fig. 105)

$K = 16R^3KC$

$K = 16 \times 3.3 \times .33 \times 4.5$

$K = 78.4$ or 78.5 kilograms of TNT per charge

5. Additional Data

Characteristics of U.S. explosives, steel cutting charges, and minimum safe distances, expressed in the metric system, are given in tables XVII, XVIII, and XIX respectively.

Table XVII. Characteristics of Principal U. S. Explosives (Metric)

Name	Velocity of detonation (meters per sec)	Relative effectiveness	Weight per block
TNT	6,900	1.00	.454 and .227 kg
Tetrytol	7,000	1.20	1.1 kg
M118 (sheet explosive).	7,190		.90 kg—block
Composition C–3.	7,625	1.34	0.22 kg—sheet 1.02 kg—M3
Composition C–4.	8,040	1.34	1.1 kg—M5 1.1 kg—M5A1
Ammonium nitrate.	3,400	0.42	0.56 kg—M112 18.17 kg
Military dynamite.	6,100	0.92	.227 kg

Table XVIII. Steel Cutting Charges (Metric)

Average thickness of section in centimeters	Kilograms of TNT for rectangular steel section of given dimensions												
	Width of Sections in Centimeters												
	5.0	7.6	10.2	12.7	15.2	20.3	25.4	30.5	35.6	40.6	45.7	50.8	61.0
.64	.09	.14	.18	.23	.27	.36	.45	.54	.64	.73	.82	.91	1.1
.95	.14	.23	.27	.32	.41	.54	.64	.77	.91	1.04	1.18	1.27	1.54
1.27	.18	.27	.36	.45	.54	.68	.86	1.04	1.22	1.36	1.5	1.7	2.0
1.59	.23	.32	.45	.54	.64	.86	1.1	1.32	1.5	1.7	1.95	2.13	2.59
1.91	.27	.41	.54	.64	.77	1.00	1.27	1.54	1.81	2.04	2.31	2.59	3.08
2.22	.32	.45	.64	.77	.90	1.22	1.5	1.81	2.08	2.4	2.7	3.0	3.6
2.54	.36	.54	.68	.86	1.04	1.36	1.7	2.0	2.4	2.7	3.1	3.4	4.1

Table XIX. Minimum Safe Distances (in the Open) (Metric)

Kilos of explosives	Safe distance in meters	Kilos of explosives	Safe distance in meters
.45 to 12 kilos	274	34	384
13	281	36	393
14	290	40	410
16	302	45	424
18	311	56	457
20	320	62	486
22	329	90	534
23	337	136	612
25	348	181	673
27	357	226	726
29	366	Over 226 (compute by formula)	

APPENDIX C

USE OF LAND MINES, AERIAL BOMBS, AND SHELLS AS DEMOLITION CHARGES

1. Introduction

When land mines, aerial bombs, and shells are used as demolition charges, special precautions must be taken because of flying steel fragments. The use of such mines, bombs, and shells is generally uneconomical but may at times become necessary or desirable. Such material may be issued from captured or friendly supply stocks or, in the case of land mines, may be those recovered from enemy or friendly minefields. *In no case should unexploded dud shells or bombs be used for demolition purposes.*

2. Land Mines

a. Safety Precautions. Only defuzed mines should be used in demolition charges, as fused mines recovered from minefields may be sensitive because of near misses and may be detonated by even normal handling. The use of enemy mines salvaged from minefields or dumps is regulated by directives issued from headquarters of the theater concerned. United States and foreign land mines are described in detail in TM 9–1345–200, TM 5–280, and TM 5–280A.

b. Charges. In calculating demolition charges when using mines, only the explosive weight is considered. Normal explosive quantities may be used for cratering or pressure charges with mines; but, because of poor contact of the mine case against irregularly shaped objects, it may be necessary to increase cutting charges considerably. Test shots will determine the results to be obtained under given conditions. A list of antitank mines in current use by the United States and (in current use or obsolete in foreign armies) with their explosive weights is given below. Information, however, on the type of explosive used is not always available—

(1) *United States*

Type Mine	*Explosive*
M7A2 A/T (metallic)	3⅝ lb TNT
M6A2 A/T (metallic)	12 lb TNT
M15 A/T (metallic)	22 lb TNT
M19 A/T (nonmetallic)	21 lb TNT
M21 A/T (metallic)	10½ lb composition H6

(2) *Foreign Mines*

(*a*) *Austria*

Barrier A/T (metallic)	10 lb

(*b*) *Belgium*

Model VI A/T (metallic)	6 lb
BSB A/T (metallic)	7.75 lb TNT
Type H A/T (metallic)	12.75 lb TNT
Type HA A/T (metallic)	12.75 lb TNT

(*c*) *Communist China*

Dual purpose No 8 (metallic).	5 lb
Dual purpose No 4 (metallic).	12 lb
Model 1951 A/T (wooden)	13.8 lb TNT

(*d*) *Czechoslovakia*

PT-Mi-K A/T (metallic)	11 lb TNT
PT-Mi-D A/T (wooden)	6 lb TNT (approx)
PT-Mi-Ba A/T (plastic or bakelite).	15 lb cast TNT

(*e*) *Finland*

M 36 A/T (metallic)	8 lb TNT
M 39 A/T (metallic)	8.8 lb TNT

(*f*) *France*

M1935 heavy A/T (metallic).	3.25 lb
M1936 light A/T (metallic).	5.75 lb
M1948 A/T (metallic)	11.5 TNT or MD (20% dinitronapthalene and 80% picric acid*)
M1948 plate charge A/T (metallic).	16 lb TNT or picric acid*
M1951 shaped charge A/T (metallic).	4 to 5 lb hexolite
Model 1947 A/T (plastic)	12.1 lb TNT
Model 1951 A/T (Caseless)	16–20 lb cast TNT

(*g*) *Hungary*

CVP–1 variable pressure, general purpose (metallic).	3.5 lb TNT

See footnote on page 158.

Type Mine	Explosive
(h) Japan (WW II)	
Type 93 antivehicular (metallic).	2 lb picric acid*
Yardstick antivehicular (metallic).	6 lb picric acid*
Model 1 beach mine (double horn) (metallic).	40.6 lb trinitroanisol
Model 2 beach mine (single horn) (metallic).	22 lb
(i) Netherlands	
Type II A/T (metallic)	9 lb
Mushroom-topped dual purpose (metallic).	5.25 lb TNT
(j) South Korea	
Heavy A/T mine (metallic)	22 lb TNT
Type I dual purpose (metallic).	5.7 lb flaked TNT
Type II dual purpose (metallic).	4.5 lb TNT
(k) USSR	
PMZ–40 A/T (metallic)	8 lb
TM–35 A/T (metallic)	8.8 lb
TM–38 A/T (metallic)	6.5 lb
TM–41 A/T (metallic)	8 lb amatol 80/20 or flaked TNT (picric acid* booster)
T-IV A/T (metallic)	6.2 lb
AKS general purpose (metallic).	13.2 lb
TMD-B A/T (wooden)	11–15 lb pressed amatol, dynammonite, cast TNT, or powdered picric acid*
TMB–44 A/T (wooden)	11–15.4 lb amatol, dynammonite, or TNT
TMB–2A/T (tar-impregnated cardboard).	11 lb powdered amatol 80/20
TMS–B A/T (tar-impregnated cardboard).	13 lb powdered amatol 80/20
(l) United Kingdom	
Mark 2 EP A/T (metallic)	4.5 lb TNT
Mark 2 GS A/T (metallic)	4 lb TNT or baratol (barium nitrate and TNT–20/80 or 10/90)
Mark 3 GS A/T (metallic)	4.5 lb TNT
Mark 4 GS A/T (metallic)	8.25 lb TNT
Mark 5 GS A/T (metallic)	4.5 lb TNT
Mark 5 HC A/T (metallic)	8.3 lb TNT
Mark 6 EP and Mark 5 C A/T (metallic)	4.5 TNT

* *Picric acid corrodes metals, forming extremely sensitive compounds, easily detonated. Mines loaded with this explosive should not be handled except to move them to a safe disposal area for destruction.*

c. Priming. Land mines are detonated by means of a pound of explosive placed on the pressure plate. If large quantities of mines are to be fired simultaneously, several mines are primed to insure complete detonation. Detonation of a single mine normally detonates other mines in contact with it.

3. Aerial Bombs

a. Use. General-purpose aerial bombs may be used satisfactorily as demolition charges but are more effective as cratering charges. Their shape makes them inefficient for demolitions requiring close contact between the explosive and the target. Precautions must be taken to avoid damage to installations and injury to personnel because steel fragments of the bomb case are thrown great distances. Before using a bomb, it must be positively identified as a general-purpose bomb.

b. Charges. The explosive content of bombs is approximately half their total weight. Table XX gives the weight of high explosive in various types of general-purpose bombs. Approximately 20 percent of the explosive power is expended in shattering the case.

Table XX. Explosive Content of General-Purpose Bombs

Bomb	Total weight (lb)	Explosive weight (lb)
100-lb GP, AN–M30A1	115	57
250-lb GP, AN–M57A1	260	125
500-lb GP, AN–M64A1	525	266
1,000-lb GP, AN–M65A1	990	555
2,000-lb GP, AN–M66A2	2,100	1,098
3,000-lb GP, T–55	2,605	1,710

c. Priming. Bombs under 500 pounds weight are detonated by firing a 5-pound explosive charge in good contact in the middle of the case. Bombs of 500 pounds or more are detonated by a 10-pound charge similarly placed. Fuses should not be positioned on the nose or tail. To insure detonation, large bombs should be primed separately.

4. Artillery Shells (Nonnuclear)

Artillery shells are used for demolition only where a fragmentation effect is desired. Because of their low explosive content they are seldom used for other demolition purposes. The

105-mm howitzer HE shell, which weighs 33 pounds, contains only 5 pounds of explosive; while the 155-mm howitzer shell contains only 15 pounds. Shells up to 240-mm are detonated by 2 pounds of explosive placed in good contact with the case, just forward of the rotative band. To insure complete detonation, a charge should be placed on each shell. The universal destructor M10 (para 40*a*) may be used to detonate projectiles or bombs that have 1.7- or 2-inch diameter threaded fuse wells. The booster cavities of bombs and large projectiles should be filled to the full depth by adding booster cups to the destructor M10 as required.

APPENDIX D

SUMMARY OF EXPLOSIVE CALCULATION FORMULAS

1. Timber-Cutting Charges

a. External Charges, Untamped (para 78*a*).

$P = \frac{D^3}{40}$

P = pounds of TNT required

D = diameter of the timber in inches or the least dimension of dressed timber.

b. Cutting Trees to Create an Obstacle (para 78*b*).

c. Internal Charges, Tamped (para 78*c*).

$P = \frac{D^3}{50}$

P = pounds of any explosive

D = diameter, or the least cross-sectional dimensional in inches.

2. Steel-Cutting Charges

a. Structural Members (para 81*b*(1)).

$P = \frac{3}{8} A$

P = pounds of TNT required

D = cross-sectional area in square inches of the steel member to be cut.

b. Other Steel Members (para 81*b*(2)(*a*)).

$P = D^2$

P = pounds of TNT required

D = diameter, in inches, of section to be cut.

c. Steel Bars 2 Inches in Diameter or Less (para 81*b*(2)(*b*)).

P = D

P = pounds of TNT required

D = diameter of bar in inches or largest dimension of section to be cut.

Rule of thumb.

Bars up to 1 inch in diameter, use 1 pound TNT.

Bars over 1 inch in diameter and up to 2 inches, use 2 pounds TNT.

d. Railroad Rails.

To cut 80-pound or lighter rail (5 inches or less in height), use ½ pound of explosive

To cut rails over 80 pounds (over 5 inches high), use 1 pound of explosive.

e. Saddle Charge (para 83*b*).

Base of charge = ½ circumference of target (fig. 100).

Long axis of charge = circumference of target

Thickness of charge = 1/3 thickness of M5A1 block (2/3 inch) for targets up to 19 inches in circumference (6 inches in diameter); ½ the thickness of M5A1 block (1 inch) for targets from 19 to 25 inches in circumference (over 6 to 8 inches in diameter).

Note. Steel alloy targets over 25 inches in circumference (over 8 inches in diameter) require the diamond charge.

f. Diamond Charge (para 83*c*).

Long axis of charge = circumference of target (fig. 101).

Short axis of charge = ½ circumference of target

Thickness of charge = 1/3 thickness M5A1 block (2/3 inch)

g. Ribbon Charge (para 83*d*).

Thickness of charge = ¾ thickness of target (fig. 102)

Width of charge = 3 × thickness of charge

Length of charge = length of cut.

3. Pressure Charges

(para 84)

$P = 3H^2T$

P = pounds of TNT required for each stringer

H = height of stringer, including thickness of roadway

T = thickness in feet of stringer in feet

The values of H and T, if not whole numbers, are rounded off to the next higher quarter-foot dimension. Neither H nor T is ever considered to be less than 1 in the formula.

Note. Increase the calculated charge P by one-third if it is not tamped.

4. Breaching Charges

a. Size of Each Charge (para 86*a*).

$P = R^3KC$

P = pounds of TNT required.

R = breaching radius in feet (rounded off to the next higher ½-foot).

K = material factor (table XI).

C = tamping factor (fig. 105).

Note. Add 10 percent to the calculated charge whenever P is less than 50 pounds and increase the charge by 50 percent for walls 1 foot thick or less.

b. Number of Charges (para 87*b*).

$$N = \frac{W}{2R}$$

N = number of charges

W = width of pier, slab, or wall in feet

R = breaching radius in feet

When the value of N has a fraction less than ½, the fraction is disregarded, but when the fraction is ½ or more, the value is rounded off to the next higher whole number. An exception to the general rule is the N-value between 1 and 2, wherein a fraction less than ¼ is disregarded, but a fraction of ¼ or more is rounded off to the next higher whole number, 2.

5. Cratering Charges

a. Deliberate Method (para 89). Forty-pound charges in 5-foot boreholes are alternated with 80-pound charges in 7-foot boreholes. All boreholes are placed on 5-foot centers. The end holes in all cases are 7 feet deep. No two 5-foot holes should be adjacent to each other (fig. 107).

b. Hasty Method (para 90). Ten pounds of explosive per foot of borehole is placed in holes of equal depth. Boreholes are positioned on 5-foot centers at depths varying from 2½ to 5 feet (fig. 108).

c. Relieved Face Crater (para 91*a*). Two rows of boreholes are drilled 8 feet apart (fig. 109); boreholes are spaced on 7-foot centers—four on the friendly side and three staggered between them on the enemy side. Boreholes on friendly side are 5 feet deep and loaded with 40 pounds of explosive, and on the enemy side, 4 feet deep and loaded with 30 pounds of explosive. Row on enemy side is detonated first and on the friendly side, ½ to 1½ seconds later.

d. Angled Crater (para 91*b*). A line of boreholes is blasted or drilled across a roadway at a 45° angle (fig. 110). Standoff distance for M2A3 shaped charge for boring holes on unpaved roads is from 20 to 30 inches; and on paved roads, about 36 inches. Increase in standoff distance increases depth of borehole but decreases its diameter.

6. Breaching Hard-Surfaces Pavements

Charges are computed on the basis of 1 pound of explosive per 2 inches of pavement thickness. Tamping should be twice the thickness of the pavement (para 88*b*(2)).

7. Computation of Minimum Safe Distances

a. For charges less than 28 pounds, the minimum safe distance is 900 feet. This, however, gives no insurance against missile hazards, which require a defilade.

b. For charges from 28 to 500 pounds, the safe distance is computed by means of this formula:

Safe distance in feet =

$$300 \sqrt[3]{\text{pounds of explosive}}$$

c. For quarrying operations the formula is:

Safe distance in feet =

$$350 \sqrt[3]{\text{pounds of explosive}}$$

8. Notes

a. The charges calculated by the above formulas should be rounded off to the next higher unit package of explosive being used or cut, when applicable.

b. When an explosive other than TNT is used in external charges computed from the steel, timber, breaching, or pressure formula, the value of P should be adjusted by use of the relative effectiveness factor as indicated in table VIII.

APPENDIX E

POWER REQUIREMENTS FOR SERIES FIRING CIRCUIT

1. Series Circuit

In demolition projects, electric blasting caps are connected in series and fired by an electric power source (blasting machine). A series circuit provides a single path for the electrical current which flows from one firing wire through each blasting cap to the next blasting cap and back to the other firing wire. A series circuit should not contain more than 50 blasting caps. The connection of more than 50 caps in a series circuit increases the hazard of breaks in the firing line or cap leads prior to the initiation of some caps.

2. Ohm's Law

The amount of voltage necessary to detonate the blasting caps in these circuits is calculated by the use of the basic law of electricity, Ohm's Law—

$E = IR$

E = electrical potential, or voltage, expressed in volts.
I = current, expressed in amperes.
R = resistance, expressed in ohms.

3. Electric Power Formula

Electrical power is computed by means of the following formula:

$W = I^2R$

W = electrical power, expressed in watts.
I = current, expressed in amperes.
R = resistance, expressed in ohms.

4. Electrical Characteristics of Electric Blasting Caps

The current needed to fire military electric blasting caps connected in series should be at least 1.5 amperes regardless of the number of caps. The resistance of a military electric blasting cap is 2 ohms.

5. Resistance of a Circuit

Resistance is computed to insure that the power source is adequate to fire all charges connected to the circuit. Both the blasting caps and the wire contained in a circuit contribute to the total resistance of that circuit. This resistance is computed from the individual resistances of the blasting caps and the wire.

Table XXI. Resistance of Various Sizes of Copper Wire

1	2	3	4
Size o copper wire			
AWG (B&S) gage No.	Diameter (in.)	Length of wire to weigh 1 pound (ft. per lb.)	Resistance of 1,000 feet of wire (ohms per 1,000 ft.)
2	3/10	5.0	0.2
4	1/4	7.9	.3
6	1/6	12.6	.4
8	1/8	20.0	.6
10	1/10	31.8	1.0
12	1/12	50	1.6
14	1/16	80	2.5
16	1/20	128	4.0
18	1/25	203	6.4
20	1/30	323	10.2

The resistance of the wire used is a circuit depends upon its size and the length. Table XXI gives the resistance per 1,000 feet of various sizes of copper wire. The total resistance in a series circuit is the sum of the resistance of the various components of that circuit. (For simplicity of calculation in the field, only the resistance of the blasting caps is used to determine the resistance of a circuit.)

6. Calculations for a Series Circuit

Complete calculations for any circuit involve the determination of the current (amperes), the voltage (volts), and the power (watts) needed to fire the circuit. Computation of the voltage and of the power requires the determination of the resistance (ohms) in the system.

a. Current Requirements. The current required for a series-connected system of special electric blasting caps is 1.5 amperes, regardless of the number of blasting caps in the circuit.

b. Resistance. The resistance of the system is computed as described in paragraph 5 of this appendix.

c. Voltage Requirements. Using Ohm's Law, $E = IR$ (para 2 this app), the voltage needed is computed by multiplying the required current (1.5 amperes) by the resistance of the system.

d. Power Requirements. By means of the electrical power formula, $W = I^2R$ (para 3 this app), the number of watts of power needed may be found by multiplying the square of the current required ($1.5^2 = 2.25$) by the resistance of the system.

e. Illustrative Problem. Determine the current, voltage, and power required to detonate the blasting caps of a circuit consisting of 20 special electric blasting caps connected in series, and 500 feet of the standard 2-conductor, 18-gage firing wire.

(1) Current required = 1.5 amperes (*a* above)

(2) Resistance:
20 blasting caps $= 2.0 \times 20 = 40$
1,000 feet No. 18 wire (table XXI) = 6.4
Total resistance = 46.4 ohms

Note. As 500-foot firing wire consists of 2 strands of No. 18 wire each 500 feet long, 1,000 feet of wire is used in the above computation.

(3) Voltage:
$E = IR$ (para 2 this app)
$E = 1.5 \times 46.4 = 69.6$ volts

(4) Power:
$W = I^2R$ (para 3 this app)
$E = 1.5^2 \times 46.4 = 2.25 \times 46.4 =$
$E = 1.5^2 \times 46.4 = 2.25 \times 46.4 =$
104.4 watts

7. Calculated Voltage Drop

In each of the examples given above the voltage drop (IR) in the blasting circuit was calculated by the use of Ohm's Law. In practice, if the calculated voltage drop exceeds 90 percent of the available voltage, it is recommended that the resistance of the circuit be decreased or the voltage be increased.

8. Capacity of Power Sources

a. Determining Capacity of Power Sources. It is possible to determine from the nameplate amperage and voltage rating whether the power source is suitable for firing an electric circuit computed by the above methods. Frequently, however, the size of a circuit that may be fired with current from a given power source may be determined by consulting table XXII which gives the maximum capacities of some power sources. If it is necessary to calculate the capacity of a given generator from the nameplate data, proceed as follows:

(1) Divide 90 percent of the voltage of the generator (para 6 this app) by the total amperage of the circuit, 1.5 amps, to determine the maximum resistance in ohms that may be in the circuit.

(2) Subtract the total wire resistance from the maximum allowable circuit resistance of caps to determine the maximum allowable resistance of the caps in the circuit.

(3) To calculate the maximum number of caps, divide the allowable resistance of the caps in the circuit by the resistance of one cap (2.0 ohms).

b. Illustrative Problem. Determine the number of military electric blasting caps in series that may be fired by a 220-volt, 13½

Table XXII. Maximum Circuit Capacities of Various Power Sources

1	2	3	4	5	6	7	8	9	10
Circuit design	Total number of caps in circuit	Power source							
		10-cap blasting machine	30-cap blasting machine	50-cap blasting machine	1½-kw portable generator, 115-volt, 13½-amp	3-kw portable generator, 115-volt, 26-amp	5-kw portable generator, 115-volt, 43½-amp	3-kw portable generator, 220-volt, 13½-amp	5-kw portable generator, 220-volt, 22½-amp
		The circuits below are connected by one 500-foot standard two-conductor firing reel							
1 10 caps in continuous series.	10	x	x	x	x	x	x	x	x
2 30 caps in continuous series.	30	-----	x	x	x	x	x	x	x
3 50 caps in continuous series.	50	-----	-----	x	-----	-----	-----	x	x

AGO 7252A

ampere generator using 500 feet of 20-gage connecting wire.

(1) Allowable resistance of circuit = $\frac{(0.90)(220)}{(1.5)}$ = 132 ohms (para 6 and 7).

(2) Resistance of firing wire = $\frac{(10.2)(500)}{1{,}000}$ = 5.1 ohms (table XXI)

(3) Allowable resistance of caps for a series circuit = 132 − 5.1 = 126.9 ohms

(4) Number of blasting caps allowed in the series circuit = $\frac{126.9}{2.0}$ = 63.4 or 63 caps (*a*(3) above).

c. Use of Storage Batteries and Dry Cells. The size of a circuit that may be fired by a battery or dry cell may be determined by following the same procedure as that outlined in *a*(1) through (3) above.

Caution: **For safety, disconnect the battery terminal prior to disassembly of the equipment where there is danger from shorting across the battery circuit. In reassembly, make the battery terminal connection last.**

APPENDIX F

SPECIAL DEMOLITION MATERIALS AND TECHNIQUES

Section I. SPECIAL CHARGES

1. Square Charge

a. Description. This technique is applicable to the demolition of concrete and masonry bridge piers and other types of construction, but not steel. The charge for use on reinforced concrete walls up to 4 feet thick is composed of composition C 4 blocks, 2 x 2 x 11 inches. They are placed as removed from the packing case. For walls from 5 up to 7 feet thick, haversacks of 8 blocks of C 4 (M5A1) explosive, measuring 4 x 8 x 11 inches each may be used. The blocks are not removed from the haversacks, as they are easily fastened against the target (fig. 121). The size of the charge depends on the thickness of the target and the ratio of the thickness of the charge and the contact area. Although these charges, if square, are more effective than if rectangular, it is not always feasible to cut them to size. As most charges are rectangular, additional explosive is allowed for modification in technique. The charges tabulated in *c* below, have proved effective.

b. Placement on Piers.

(1) Place the charge at least the thickness of the target above the base to obtain the maximum results. A small charge may be taped to the target or supported by a platform. Larger charges may be supported by strips of material and wire attached to the pier by fasteners driven into the concrete by means of the powder-actuated driver.

(2) Initiate the charge from the center (fig. 121).

(3) Mud tamp the explosive on 1-foot thick targets, as this permits a 30-percent reduction in explosive weight.

c. Charge Size.

Concrete thickness	*Charge size*	*Charge thickness*
1 ft	2 C4 blocks	One block—2 in
2 ft	4 C4 blocks	One block—2 in
3 ft	7 C4 blocks	One block—2 in
4 ft	20 C4 blocks	One block—2 in
5 ft	6 M37 kits (20 lb packet)	One kit—4 in
6 ft	8 M37 kits (20 lb packet)	One kit—4 in
7 ft	12 M37 kits (20 lb packet)	One kit—4 in

2. Foxhole Digger Explosive Kit

a. Characteristics (fig. 141)

(1) Case

Material	Shape	Size	Wt
Plastic with screw cap.	Tubular with truncated top.	7.38 x 2.28 in	1.0 lb

(2) Shaped Charge

Material	Shape	Size	Explosive Charge			
			Type	Det Vel	Wt	Booster
Copper cone with 60° angle; and plastic.	Tubular with truncated top.	7.37 x 2.0 in	Octol	27,559 fps	118g (4.16 oz)	RDX

(3) Cratering Charge

Material	Shape	Size	Explosive Charge			
			Type	Det Vel	Wt.	Booster
2 segments of pressed explosive; connecting sleeve.	Tubular	8.21 x 1.0 in	PBXN-1	24,606 fps	162g (5.71 oz)	RDX

(4) Fuzes

Material	Shape	Size	Action	Initiation	Safety	Explosive
Stainless steel body; steel coupling.	Tubular	4.25 x 0.56 in	Mechanical with spring-driven striker	Push button	Cotter pin	RDX and primer.

(5) Auxiliary items

Piece of No. 9 nylon twine 36 in long; steel stability rod 4.25 x 0.1 in; two strips adhesive-coated foam tape; and lug on side of case with hole for stability rod and a ring for attaching kit to soldier's clothing or equipment

(6) Remarks

Outer case of kit serves also as standoff for shaped charge.

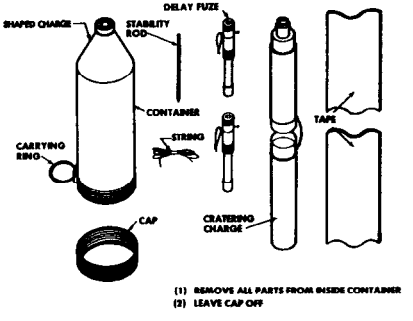


Figure 141. Foxhole digger explosive kit.

b. Effect.

(1) The shaped charge will penetrate soil, depending on the density, to depths varying from 20 to 33 inches, forming a tapered hole 2¼ inches in diameter at the top and 1 inch at the bottom. It will bore a hole through 5-inch mild steel plate, 1 inch in diameter at the entry and ¼ inch at the exit, and will penetrate concrete to a depth of 8

CRATERING : BORING HOLES

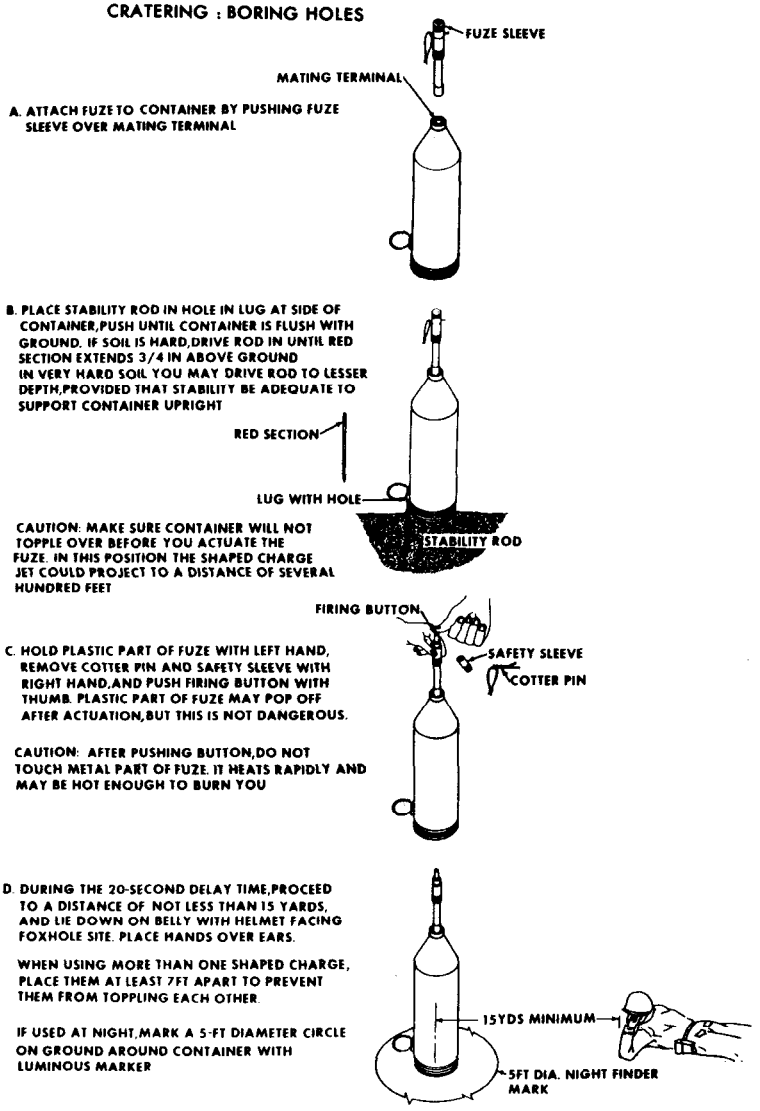

FUZE SLEEVE
MATING TERMINAL
A. ATTACH FUZE TO CONTAINER BY PUSHING FUZE SLEEVE OVER MATING TERMINAL
B. PLACE STABILITY ROD IN HOLE IN LUG AT SIDE OF CONTAINER, PUSH UNTIL CONTAINER IS FLUSH WITH GROUND. IF SOIL IS HARD, DRIVE ROD IN UNTIL RED SECTION EXTENDS 3/4 IN ABOVE GROUND IN VERY HARD SOIL YOU MAY DRIVE ROD TO LESSER DEPTH, PROVIDED THAT STABILITY BE ADEQUATE TO SUPPORT CONTAINER UPRIGHT
RED SECTION
LUG WITH HOLE
STABILITY ROD
CAUTION: MAKE SURE CONTAINER WILL NOT TOPPLE OVER BEFORE YOU ACTUATE THE FUZE. IN THIS POSITION THE SHAPED CHARGE JET COULD PROJECT TO A DISTANCE OF SEVERAL HUNDRED FEET
FIRING BUTTON
C. HOLD PLASTIC PART OF FUZE WITH LEFT HAND, REMOVE COTTER PIN AND SAFETY SLEEVE WITH RIGHT HAND, AND PUSH FIRING BUTTON WITH THUMB. PLASTIC PART OF FUZE MAY POP OFF AFTER ACTUATION, BUT THIS IS NOT DANGEROUS.
CAUTION: AFTER PUSHING BUTTON, DO NOT TOUCH METAL PART OF FUZE. IT HEATS RAPIDLY AND MAY BE HOT ENOUGH TO BURN YOU
SAFETY SLEEVE
COTTER PIN
D. DURING THE 20-SECOND DELAY TIME, PROCEED TO A DISTANCE OF NOT LESS THAN 15 YARDS, AND LIE DOWN ON BELLY WITH HELMET FACING FOXHOLE SITE. PLACE HANDS OVER EARS.
WHEN USING MORE THAN ONE SHAPED CHARGE, PLACE THEM AT LEAST 7FT APART TO PREVENT THEM FROM TOPPLING EACH OTHER.
IF USED AT NIGHT, MARK A 5-FT DIAMETER CIRCLE ON GROUND AROUND CONTAINER WITH LUMINOUS MARKER
15YDS MINIMUM
5FT DIA. NIGHT FINDER MARK

Figure 142. Arming and placement of foxhole digger explosive kit for cratering.

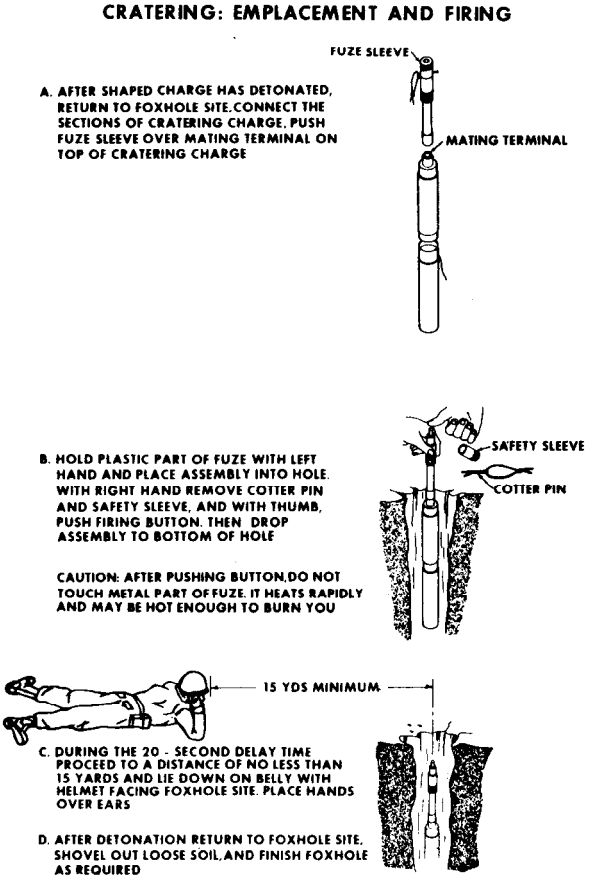

CRATERING: EMPLACEMENT AND FIRING
FUZE SLEEVE
A. AFTER SHAPED CHARGE HAS DETONATED, RETURN TO FOXHOLE SITE. CONNECT THE SECTIONS OF CRATERING CHARGE. PUSH FUZE SLEEVE OVER MATING TERMINAL ON TOP OF CRATERING CHARGE
MATING TERMINAL
B. HOLD PLASTIC PART OF FUZE WITH LEFT HAND AND PLACE ASSEMBLY INTO HOLE. WITH RIGHT HAND REMOVE COTTER PIN AND SAFETY SLEEVE, AND WITH THUMB, PUSH FIRING BUTTON. THEN DROP ASSEMBLY TO BOTTOM OF HOLE
SAFETY SLEEVE
COTTER PIN
CAUTION: AFTER PUSHING BUTTON, DO NOT TOUCH METAL PART OF FUZE. IT HEATS RAPIDLY AND MAY BE HOT ENOUGH TO BURN YOU
15 YDS MINIMUM
C. DURING THE 20 - SECOND DELAY TIME PROCEED TO A DISTANCE OF NO LESS THAN 15 YARDS AND LIE DOWN ON BELLY WITH HELMET FACING FOXHOLE SITE. PLACE HANDS OVER EARS
D. AFTER DETONATION RETURN TO FOXHOLE SITE. SHOVEL OUT LOOSE SOIL, AND FINISH FOXHOLE AS REQUIRED

Figure 142—Continued.

inches with a hole 1¼ inches in diameter at the top and ½ inch at the bottom.

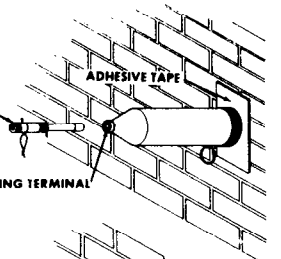
(2) The cratering charge will form a crater in soil about 42 inches in diameter and about 32 inches deep.

c. Use. For demolition purposes the shaped charge (5.71 ounces of explosive) may be useful in boring small holes in metal, concrete, wood, and soil, and in cutting small steel bars, rods, and cables. This, of course, depends on the ingenuity and initiative of the experienced demolitionist. It may be useful to damage metal working parts of vehicles and other

SHAPED CHARGE

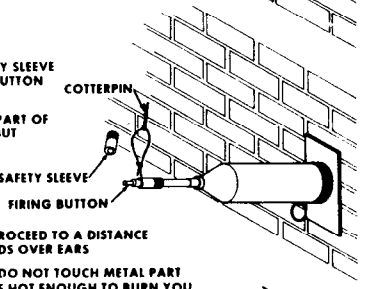
A. REMOVE PAPER FROM ONE SIDE OF ADHESIVE TAPE AND PRESS ONTO TARGET. REMOVE PAPER FROM EXPOSED SIDE OF ADHESIVE TAPE AND PRESS SHAPED CHARGE CONTAINER AND CAP AGAINEST ADHESIVE SURFACE

B. ATTACH FUZE TO CONTAINER BY PUSHING SLEEVE OVER MATING TERMINAL



C. HOLD PLASTIC PART OF FUZE WITH LEFT HAND, REMOVE COTTER PIN AND SAFETY SLEEVE WITH RIGHT HAND, AND PUSH FIRING BUTTON WITH THUMB

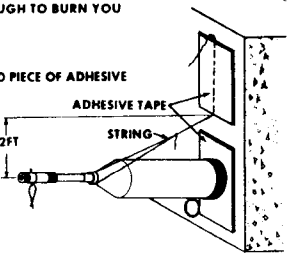
AFTER BUTTON IS PUSHED, PLASTIC PART OF FUSE MAY POP OFF AFTER ACTUATION; BUT THIS IS NOT DANGEROUS



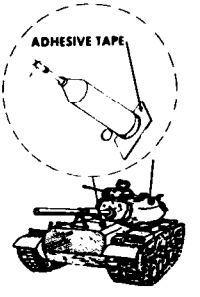
D. DURING THE 20-SECOND DELAY TIME, PROCEED TO A DISTANCE OF AT LEAST 15 YARDS, AND HOLD HANDS OVER EARS

CAUTION: AFTER PUSHING BUTTON, DO NOT TOUCH METAL PART OF FUZE. IT HEATS RAPIDLY AND MAY BE HOT ENOUGH TO BURN YOU

E. FOR PLACEMENT ON SLIMY SURFACES, USE A SECOND PIECE OF ADHESIVE TAPE FOR SUPPORT AS SHOWN



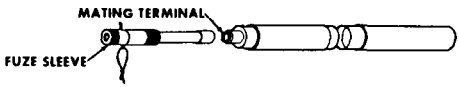
F. SHAPED CHARGE MAY BE USED TO DAMAGE ENEMY TANKS AS SHOWN



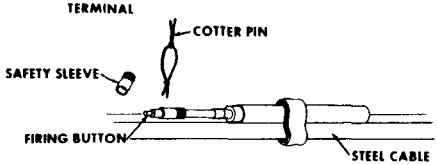
CAUTION: WHEN PLACED ON BRITTLE TARGETS, FRAGMENTS MAY BE PROJECTED BEYOND THE 15-YD MINIMUM SAFE DISTANCE

Figure 143. Arming and placement of foxhole digger explosive kit for damage.

G. CUTTING CABLE



(1). CONNECT THE TWO SECTIONS OF CRATERING CHARGE AND ATTACH FUZE TO IT BY PUSHING FUZE SLEEVE OVER MATING TERMINAL



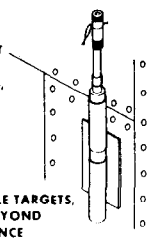
(2). REMOVE PAPER FROM ONE SIDE OF ADHESIVE TAPE AND FASTEN CRATERING CHARGE TO TARGET ,IN THIS CASE A STEEL ROD OR CABLE

(3). *HOLD PLASTIC PART OF FUZE WITH LEFT HAND,* REMOVE COTTER PIN AND SAFETY SLEEVE WITH RIGHT HAND,AND PUSH FIRING BUTTON WITH THUMB. AFTER BUTTON IS PUSHED,PLASTIC PART OF FUZE MAY POP OFF AFTER ACTUATION ;BUT THIS IS NOT DANGEROUS

(4). DURING THE 20-SECOND DELAY TIME,PROCEED TO A DISTANCE OF AT LEAST 15YDS AND HOLD HANDS OVER EARS

CAUTION: AFTER PUSHING BUTTON,DO NOT TOUCH METAL PART OF FUZE. IT HEATS RAPIDLY AND MAY BE HOT ENOUGH TO BURN YOU

H. *FOR OTHER TARGETS,SUCH AS FLAT* STEEL ,MOTOR BLOCKS,AUTO TRANSMISSIONS OR DIFFERENTIALS, YOU MAY NEED TO REMOVE THE PAPER FROM BOTH SIDES OF THE ADHESIVE TAPE



CAUTION WHEN PLACED ON BRITTLE TARGETS, FRAGMENTS MAY BE PROJECTED BEYOND THE 15-YD MINIMUM SAFETY DISTANCE

Figure 143—Continued.

equipment. The cratering charge, also being a high explosive (weighs 5.7 ounces) may be useful in cutting small metal bars, rods, and cables and in damaging equipment. Under critical conditions, however, test shots should be made to ascertain the effectiveness of the shaped

charge and cratering charge.

d. Arming and Placement.

(1) For arming procedure and placement for cratering see figure 142.

(2) For arming procedure and placement for damage, see figure 143.

Note. As the delay period of the fuze may vary from 20 to 50 seconds between units, *users should consider the delay as 20 seconds for safety reasons.*

Section II. EXPEDIENT DEMOLITIONS

3. Use of Expedient Techniques

These techniques are not presented as a replacement for the standard demolition methods but for use by experienced blasters in special projects. Availability of trained men, time, and material will generally determine their use.

4. Shaped Charges

a. Description. Shaped charges concentrate the energy of the explosion released on a small area, making a tubular or linear fracture in the target. Their versatility and simplicity make them effective against many targets, especially those made of concrete or those with armor plating. Shaped charges may be improvised (fig. 144). Because of the many variables, such as explosive density, configuration, and density of the cavity liner, consistent results are impossible to obtain. Thus experiment, or trial and error, is necessary to determine the optimum standoff distances. Plastic explosive is best suited for this type of charge. Dynamite and molten TNT, however, may be used as an expedient.

b. Preparation. Almost any kind of container is usable (fig. 144). Bowls, funnels, cone-shaped glasses (champagne glasses with the stem removed), and copper, tin, or zinc may be used as cavity liners; or wine bottles with a cone in the bottom (champagne or cognac bottles) are excellent. If none of these is available, a reduced effect is obtained by cutting a cavity into a plastic explosive block. Optimum shaped charge characteristics are—

(1) Angle of cavity = between 30° and 60° (most HEAT ammunition has a 42° to 45° angle)

(2) Standoff distance = 1½ × diameter of cone.

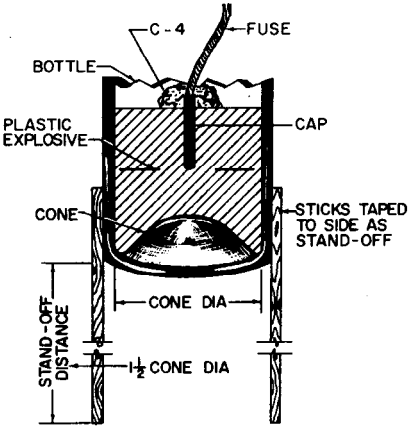


Figure 144. Improvised shaped charge.

(3) Height of explosive in container = 2 × height of cone measured from the base of the cone to the top of the explosive.

(4) Point of detonation = exact top center of charge. Cover cap, if any part of it is exposed or extends above the charge, with a small quantity of C4 explosive (fig. 144).

Note. The narrow necks of bottles or the stems of glasses may be cut by wrapping them with a piece of soft absorbent type twine or string soaked in gasoline and lighting it. Two bands of adhesive tape, one on each side of the twine or string, will hold it firmly in place. The bottle or stem must be turned continuously with the neck up, to heat the glass uniformly. Also, a narrow band of plastic explosive placed

around the neck and burned gives the same result. After the twine or plastic has burned, submerge the neck of the bottle in water and tap it against some object to break it off. *Tape the sharp edge of the bottle to prevent cutting hands while tamping the explosive in place.*

5. Opposed (Counterforce) Charge

This technique is very effective against comparatively small cubical concrete and masonry objects 4 feet or less in thickness. If properly constructed of plastic explosive, placed, and detonated, counterforce charges produce excellent results with a relatively small amount of explosive. Their effectiveness results from the simultaneous detonation of two charges placed directly opposite each other and as near the center of the target as possible (fig. 145).

a. Charge Calculation. The size is computed from the diameter or thickness of the target in feet, as—

> The amount of explosive = $1\frac{1}{2} \times$ the thickness of the target in feet ($1\frac{1}{2}$ pounds per foot).

Fractional measurements are rounded off to the next higher foot prior to multiplication. For example, a concrete target measuring 3 feet 9 inches thick requires $1\frac{1}{2} \times 4 = 6$ pounds of plastic explosive.

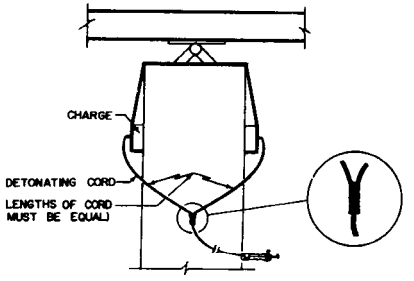


Figure 145. Opposed charge.

d. Preparation and Emplacement. Divide the calculated amount of explosive in half to make two identical charges. The two charges *must* be placed diametrically opposite each other. This requires accessibility to both sides of the target so that the charges may be placed flush against the respective target sides.

c. Priming. The simultaneous explosion of both charges is mandatory for optimum results. Crimp nonelectric blasting caps to *equal lengths* of detonating cord. Prime both charges at the *center rear point;* then form a V with the free ends of the detonating cord and attach an electric or nonelectric means of firing.

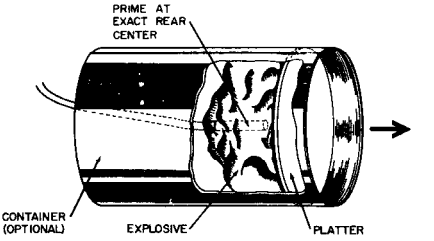


Figure 146. Platter charge.

6. Platter Charge

This device produces the Miznay-Chardin effect. It turns a metal plate into a powerful blunt-nosed projectile (fig. 146). The platter should be steel (preferably round, but square is satisfactory) and should weigh from 2 to 6 pounds.

a. Calculations. Weight of explosive = approximately the weight of the platter.

b. Preparation.

(1) Pack the explosive uniformly behind the platter. A container is not necessary if the explosive can be held firmly against the platter. Tape is acceptable.

(2) Prime the charge from the exact rear center. Cover cap, if any part is exposed, with a small quantity of C4 explosive to insure detonation.

(3) Aim the charge at the direct center of the target.

c. Effect. The effective range (primarily a problem of aim) is approximately 35 yards for a small target. With practice, a demolitionist may hit a 55-gallon drum, a relatively small

target, at 25 yards about 90 percent of the time.

7. Grapeshot Charge (Improvised Claymore)

This charge consists of a container, preferably a No. 10 can, projectiles (small pieces of steel), buffer material, an explosive charge, and a blasting cap. These are assembled as shown in figure 147.

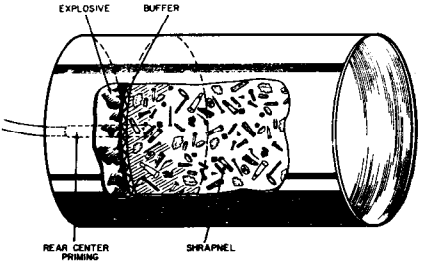


Figure 147. Grapeshot charge.

a. Computation. The weight of the explosive is approximately $\frac{1}{4} \times$ the weight of the projectiles.

b. Preparation.

(1) Assemble the projectiles, a few inches of buffer material—earth, leaves, wood, felt, cloth, cardboard, etc., and the explosive charge. This should be C4, packed firmly.

(2) Prime the charge from the exact rear center. Cover the cap, if any part is exposed, with a small quantity of C4 to insure detonation.

(3) Aim the charge toward the center of the target.

8. Dust Initiator

This device consists of an explosive charge (powdered TNT or C3; C4 will not properly mix with the incendiary), an incendiary mix (2 parts of aluminum powder or magnesium powder to 3 parts of ferric oxide), and a suitable finely-divided organic material (dust) or a volatile fuel such as gasoline called a surround. The dust initiator is most effective in an inclosed space, like a box car or a warehouse or other relatively windowless structure. At detonation, the surround is distributed throughout the air within the target and ignited by the incendiary material.

a. Computation.

(1) Charge size = 1 pound ($\frac{1}{2}$ explosive, $\frac{1}{2}$ incendiary mix).

(2) Cover size = 3 to 5 pounds for each 1,000 cubic feet of target. The one-pound charge will effectively detonate up to 40 pounds of cover.

b. Preparation. Powdered TNT may be obtained by crushing it in a canvas bag. The incendiary mix must be thoroughly dispersed throughout the explosive. A great number of dust materials may be used as cover, among which are coal dust, cocoa, bulk powdered coffee, confectioners sugar, tapioca, wheat flour, corn starch, hard rubber dust, aluminum powder, magnesium powder, and powdered soap. If gasoline is used, 3 gallons is the maximum, as more will not disperse evenly in the air and thus give poor results.

9. Improvised Cratering Charge

This charge is a mixture of ammonium nitrate fertilizer containing at least 33 1/3 percent nitrogen and diesel fuel, motor oil, or gasoline at a ratio of 25 pounds of fertilizer to a quart of fuel. The fertilizer must not be damp. From this mixture, improvised charges of almost any size or configuration can be made.

a. Pour the liquid on the fertilizer.

b. Allow the mixture to soak for an hour.

c. Place about half the charge in the borehole. Then place the primer, a primed 1-pound block of TNT, and add the remainder of the charge. Never leave the charge in the borehole for a long period, as accumulated moisture reduces its effectiveness.

d. Detonate the charge.

10. Ammonium Nitrate Satchel Charge

While the cratering charge (para 9 above) is excellent, it is suitable only for cratering. A more manageable charge may be used by mixing ammonium nitrate fertilizer with melted wax instead of oil. The primer is set in place before the mixture hardens.

a. Preparation.

(1) Melt ordinary paraffin and stir in ammonium nitrate pellets, making sure that the paraffin is hot while mixing.
(2) Before the mixture hardens add a half-pound block of TNT or its equivalent as a primer.
(3) Pour the mixture into a container. Shrapnel material may be added to the mixture if desired or attached on the outside of the container to give a shrapnel effect.

b. Use. Because the wax and fertilizer may be molded into almost any size or shape, it may be applied to a great many demolition projects with satisfactory effects.

Section III. COMMODITIES USEFUL FOR MAKING IMPROVISED EXPLOSIVE

11. Introduction

This section deals with materials usable in the manufacture of homemade explosives, incendiaries, and delay devices. Below is a partial list of commodities obtainable commercially that may be used. A glance at this list will show the great complexity of the problem of security forces who must deny these to insurgents. The strictest possible control of their purchase and sale is imperative at the earliest possible moment.

12. Commodity List

The list is as follows:

Ammonium nitrate (fertilizer)
Ammonium perchlorate
Charcoal
Coal
Common match heads
Calcium carbide
Catechol
Dinitrobenzine
"Duco" cement
Flake aluminum
Fuel oil
Glycerin
Hydrogen peroxide (10 volume or higher)
Kerosene
Limed rosin
Liquid floor wax
Lead dioxide
Lead tetraethyl
Manganese dioxide
Mercury or mercury salts
Nitrobenzine
Nitromethane
Nitrocellulose (pyroxylin)
Sodium chlorate
Sugar
Sawdust
Coal dust
Cocoa
Powdered coffee
Confectioners sugar
Tapioca
Wheat flour
Powdered rice
Cornstarch
Hard rubber dust
Cork dust
Powdered soap
Gasoline
Photoflash powder
Picric acid (certain dye derivatives)
Phenol
Potassium permanganate
Potassium nitrate
Potassium chlorate
Powdered aluminum
Powdered magnesium
Powdered zinc
Paraffin
Petroleum jelly
Pitch
Rosin
Resorcinol
Red phosphorous
Sodium nitrate
Sulfur
Sulfuric acid
Stearic acid
White phosphorous
Nitric acid
Calcium hypochlorite
Turpentine
Potassium dichromate
Sodium peroxide
Nitric acid
Copper sulfate
Carbon disulfide

Plaster of Paris
Ferric oxide
Barium peroxide
Red lead
Ferric sulfate
Aluminum powder
Aluminum sulfate
Naphtha
Silver nitrate powder

Note. As a rule, improvised explosives and incendiaries are more dangerous to handle than conventional explosives. Many mixtures may be ignited or detonated by a single spark, excessive heat, water, or the friction generated by stirring or mixing the ingredients together. Thus, only those who are well informed on the characteristics and reactions of the ingredients should attempt to make improvised explosives.

Section IV. UNDERWATER DEMOLITIONS

13. Introduction

Underwater demolitions involve four basic procedures—reconnaissance in search of obstacles, charge priming, charge placement, and charge initiation.

a. Reconnaissance. As a map may show only the superficial character of a water obstacle, the important information must be obtained by on-site physical reconnaissance by men trained in underwater techniques.

b. Types of Obstacles. Two types of obstacles may be found under water—natural and artificial. Natural obstacles include steep banks, debris, floating logs and brush, underwater ledges, natural craters (particularly at ford sites), rocks, shoals, sandbars, islands, icecrust, and floating ice. Artificial obstacles consist of land mines, boobytraps, floating mines, mines attached to submerged poles, floating obstacles, craters, concrete walls, barbed wire, and conventional concrete and metal obstacles generally found on land but often very effective under water.

14. Priming Underwater Charges

a. Explosive.

(1) *Types.* Tetrytol (M1 chain and M2 blocks), Composition C–3 (M3 and M5 blocks), TNT, and bangalore torpedoes are adaptable to underwater demolitions. Tetrytol may be submerged in water as long as 24 hours without any appreciable effects on its explosive characteristics, while C3 and TNT may be submerged longer if they remain in the original package or are placed in some other sort of container. In addition two U. S. Navy charge assemblies—Mk 133 models 0 and 2 and Mk 135 model 0—are recommended for use under water. They should not be submerged longer than 3 hours before firing, however.

(2) *Mk 133 model 2 demolition charge assembly.*

(*a*) *Characteristics* (fig. 148).

Container	Color	Size	Weight
Mk 2 model 0 canvas haversack with waterproof, fireproof and mildew-resistant treatment.	Gray	10 x 12 x 9 in	23.5 lb

Explosive		Accessories	Remarks
Main charge	Booster		
8 blocks H BX–1, 2.5 lb each, strung 1 ft apart on det cord.	50/50 pentolite located at center of block.	10 ft of sash cord with 2 flat hooks for lashing to obstacle; flotation bladder for towing; and tow ring.	Resembles M1 chain demolition charge. Five-foot length of det cord extends from each end of charge.

(*b*) *Use.* The assembly is a source of eight individual demolition charges—for placing singly or as multiple charges—by cutting the detonating cord chain.

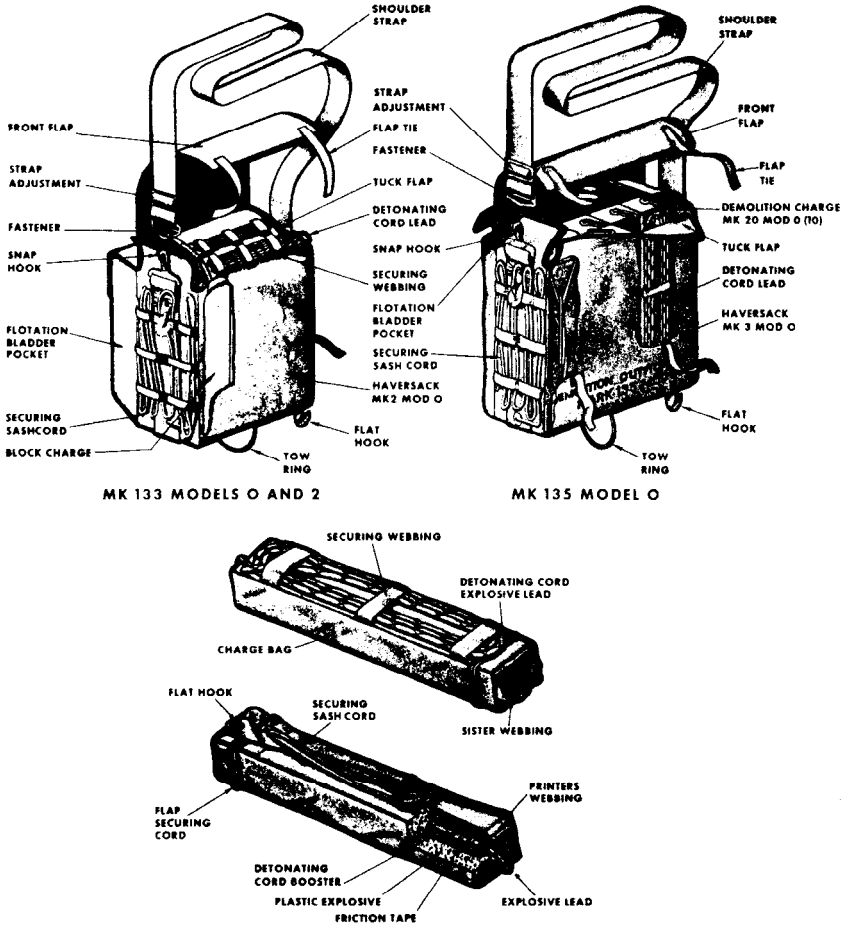


Figure 148. U. S. Navy demolition charge assemblies.

(3) *Mk 135 Model 0 demolition charge assembly.*

(*a*) *Characteristics* (fig. 148).

(*b*) *Use.* The individual explosive charge, being tightly wrapped in a canvas bag, cannot be molded into

Container	Color	Size	Weight
Mk 3 model 0 haversack with waterproof, fireproof, and mildew-resistant treatment.	Gray	12 x 14 x 9 in	24 lb (approx)

Explosive		Accessories
Main Charge	Booster (reinforced)	
10 blocks composition C3 (Mk 20 model 0), 2-lb each, in individual canvas charge bags.	5-ft length of reinforced det cord, looped to make a 1-ft booster core, molded into explosive block.	Each charge has a 3.5-ft sash cord and flat hook for lashing to obstacle. Haversack has a 10-ft sash cord and 2 flat hooks for lashing to obstacle, a flotation bladder for towing by swimmer, and a tow ring.

Remarks. Each charge has an 11-ft length of reinforced detonating cord—5 ft is looped and molded in the block and the remaining 6 ft is an explosive lead.

any desired shape, but it can be bent or curved into close contact with the surface of the target.

b. Priming. Because detonating cord, though watersoaked, may be detonated if initiated at a dry end, it is the most satisfactory of all firing systems for priming explosive charges used on underwater obstacles. M1 chain, M2, M3, M5, M5A1, M112, and TNT blocks are primed by detonating cord as described in paragraphs 64 and 65. Bangalore torpedo sections are primed as described in paragraph 69*b*. Although the M1 chain demolition block may be primed by means of a branch line attached to the detonating cord chain, priming is more positive if the detonating cord primer is wrapped and tied around the end of the block over the booster. The same is true of priming the M2 block. The 2.5-lb. block of the Mk 133 model 0 assembly should be primed by wrapping and tying the detonating cord around the center over the booster; while the M3, M5, M5A1, M112, and TNT, having no boosters, may be primed anywhere on the block (para 64).

15. Charge Placement

a. In underwater demolitions both single and multiple charges are used, depending on the size and configuration of the target. The size of the charge is computed by the applicable table or formula, but because of the tamping effect of the water, charges on underwater targets require only about 1/3 as much explosive as untamped charges used on similar targets on land. Water-tamped charges, however, require the same amount of explosive as tamped charges on land.

b. Multiple charges are connected by detonating cord branch lines attached by means of *knots* to a main line or a ring main as described in paragraph 70*b* through *d*.

c. The following procedures should be followed, if possible, in underwater demolitions. Charges should be placed so that—

(1) Their pressure waves will not counteract each other. To avoid this, charges are placed in staggered lines—the adjacent charges containing different amounts of explosive. For example, if the first charge is 20 pounds, the second should be 10 pounds, the third, 20 pounds and so on.

(2) Their fragments will not be thrown toward friendly troops and equipment.

(3) They will not throw heavy debris in or partially obstruct a path to be taken by friendly troops or equipment. For example, a charge placed on top of a boulder may merely leave the large fragments that remain as obstructions, and a charge placed directly under a boulder may form a few large fragments and a large crater underneath, thus enlarging instead of removing the obstacle. On the other hand, a snakehole charge properly placed may move the boulder and fragments from the path. These principles also apply to the removal of other obstacles.

16. Charge Initiation

Detonating cord systems used underwater may be initiated by an electric or nonelectric detonating assembly attached to a dry end of the ring main by means of a square knot (para 70*a*, fig. 85) or by means of an electric or nonelectric firing system attached directly to the ring main.

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Professional Knowledge Gained from Operational Experience in Vietnam, 1969, Special Issue, Mines and Boobytraps

U.S. Marine Corps

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DEPARTMENT OF THE NAVY
Headquarters United States Marine Corps
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20 July 1989

FOREWORD

1. PURPOSE

Fleet Marine Force Reference Publication (FMFRP) 12-43, *Professional Knowledge Gained from Operational Experience in Vietnam, 1969, Special Issue, Mines and Boobytraps*, is published to ensure the retention and dissemination of useful information which is not intended to become doctrine or to be published in Fleet Marine Force manuals. FMFRPs in the 12 Series are a special category of publications: reprints of historical works which were published commercially or by the U.S. Government Printing Office and are no longer in print.

2. SCOPE

This reference publication complements existing training manuals on small-unit tactics, patrolling, weapons, mines and boobytraps, and leadership. Written by a multitude of Marines during the Vietnam War, this volume is an excellent compendium of lessons to be learned from the Marine Corps' experience in 1969. It is enthusiastically recommended to all junior officers, SNCOs, and NCOs who will profit from the principles presented.

3. CERTIFICATION

Reviewed and approved this date.

BY DIRECTION OF THE COMMANDANT OF THE MARINE CORPS

M. P. SULLIVAN
Major General, U.S. Marine Corps
Deputy Commander for Warfighting
Marine Corps Combat Development Command
Quantico, Virginia

DISTRIBUTION: "11 9"

MINES AND BOOBYTRAPS

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SECTION I

ENEMY MINE WARFARE

INTRODUCTION

The history of mine and boobytrap warfare is almost as long as the history of war itself. Although these devices were once considered an unfair and cowardly manner of fighting an enemy, nations continued to develop and employ mines and boobytraps because they provided an effective and simple means of inflicting casualties upon an enemy force.

During the war with France, 1946-1954, the Viet Minh used improvised explosive mines and boobytraps effectively against the French forces. The VC/NVA have continued to improve upon these techniques and are employing mines and boobytraps as an effective weapons system against free world military forces in SVN today. The number of Marine casualties, perhaps better than any other example, illustrates how effective the enemy is with these devices. Marines landed in force in SVN during March 1965 and during the first months of fighting approximately 65-75 percent of all Marine casualties were caused by mines and boobytraps. Much has been learned about the enemy's methods of employing mines and boobytraps since March 1965, but despite this knowledge, Marines, at an alarming rate, continue to become casualties as a direct result of enemy mines and boobytraps. During 1968, 37.7 percent of all Marine casualties were caused by the accidential detonation of a mine or boobytrap. In other words, more than one of every three Marines killed or

wounded in SVN becomes a casualty as the result of a mine or boobytrap. Although a great many detection means, ranging from intricate electronic devices to specially trained dogs, have been developed, experience has shown that an alert Marine, aware of what to look for and where to look, is the most effective detection device.

The information contained in this book is intended to make each Marine aware of the ways which the VC/NVA use mines and boobytraps and to describe the means to effectively protect one's self and unit from these devices. To aid in this objective, mines and boobytraps frequently used by the VC/NVA are identified and described.

Study this issue; the information in it can save lives -- yours and your fellow Marines'.

******

ENEMY DOCTRINE

Although modified by past guerrilla warfare experience in Vietnam, VC/NVA mine warfare doctrine continues to closely parallel that of the Chinese Communist Army. Extensive deliberate minefields have not been encountered in Vietnam. Rather, the enemy employs mines singly or in clusters to achieve his purposes.

In areas occupied and protected by free world forces, the enemy employs mines to delay and disrupt the use of roads and paths and to cause the allies to divert forces to guard and clear those routes. In addition to the threat to military traffic and lawful civilian movement, the free world personnel and equipment employed in patrolling the roads and in detecting and removing mines are prime targets.

In contested areas where friendly offensive operations or patrol activities are conducted, the enemy employs mines and boobytraps to inflict casualties, delay and channelize movement, and damage or destroy equipment.

******

ENEMY SOURCES OF SUPPLY

The enemy uses a very limited number of modern machine-produced mines. The majority of enemy mines are handmade by the VC using U.S. duds, discarded ammunition and equipment, and materials thrown away by U.S. forces as trash. Ninety percent of all the material in enemy mines and boobytraps is of U.S. origin (see fig.1). Of all the explosive devices produced locally in VC mine factories, 95 percent are antipersonnel boobytraps.

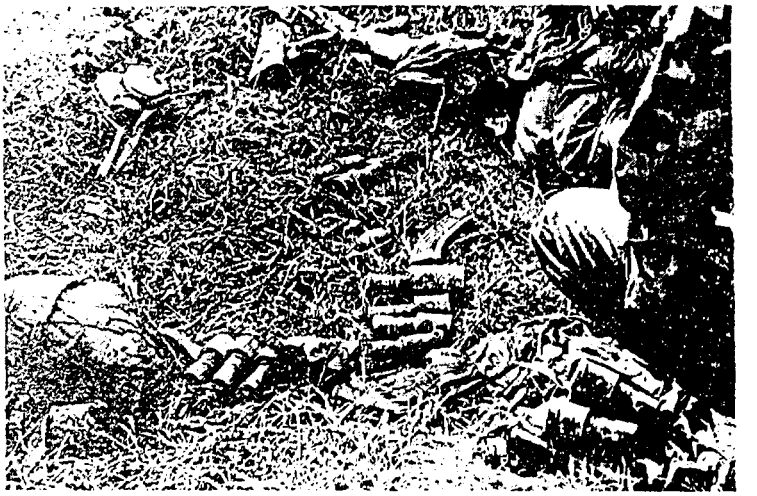


Figure 1.--Enemy equipment captured by Marines on sweep operations in ICTZ. Note US M-26 grenade in center of picture. Other grenades are locally produced using C-ration cans.

All dud ammunition is a source of enemy supply. After airstrikes and artillery and mortar missions, enemy salvage teams make sweeps to collect duds. Lighter ordnance is carried away to preparation areas; large bombs and projectiles are broken down and stripped on the spot. In some cases the larger duds are rigged as boobytraps where they have fallen. This is especially true when the enemy feels the strike or fire mission was a preparation for an infantry attack.

However, dud ammunition is not the only source of enemy supply. Carelessly discarded ordnance of all sizes and in any quantity is collected by enemy salvage teams. Mortar rounds, rockets, LAAW's,

grenades, and small arms ammunition abandoned to lighten the load (or improperly secured and lost by fast-moving Marines) have value as the explosive element in boobytraps. Even a single M16 round ejected to clear a stoppage can be used by the enemy.

Additionally, materials discarded as trash and improperly destroyed such as ration, ammunition, beer and soda cans, batteries, waterproof packaging materials, bandoliers, etc., provide the enemy a valuable source of supply to support his mine warfare operations. These items have, on numerous instances, been employed successfully against Marines and their equipment. Thorough police of friendly positions upon departure and complete destruction of trash are mandatory to deny the enemy this source of supply.

******

VC MINE FACTORIES

Primitive VC mine factories are usually located in the areas they supply. Great care is taken in the camouflage and dispersal of these facilities. Usually constructed underground, effort is made to disperse the workshops and storage throughout a series of tunnels. These limit destruction by working accidents or free world force artillery, air and naval gunfire and protect against discovery. As important as concealment of the mine factory, is the mobility of its personnel and equipment. Even while the mine factory is being settled in one position, new positions are being prepared for rapid displacement. Rarely does a mine factory

remain in one place any longer than a few weeks. There is no distinct pattern of movement. Factories have been known to return to previous positions even after that position has been discovered and destroyed by Marine forces.

NVA-trained engineers provide the skilled nucleus for the enemy mine factories, but supervision and labor are primarily VC. The typical output of a local VC mine factory is about 135 mines and explosive devices per month.

******

ENEMY TACTICS

ANTITANK AND ANTIVEHICULAR MINING

As we improve in our ability to detect mines, the enemy counters with new twists such as increased use of boobytraps attached to a basic mine to create casualties among mine-clearing personnel; larger mines buried deeper with reduced activation pressure; and pressure electric detonators with offset devices to explode mines under vehicles. Command-detonating mines are normally used in densely populated areas and pressure-type devices in less populated sections. The heaviest mining is along lines of communications near fixed installations.

The enemy makes every effort to avoid repeating practices which, when analyzed, could indicate a pattern. Therefore, the VC/NVA doctrine stresses <u>where</u> to use mines, not how. Listed below are a few of the kinds of places where enemy antitank and antivehicular mines may be found:

- Road junctions and the areas in the vicinity of the road near the junction,

with all the mines set to detonate simultaneously.

- Bridges and the approaches 5 to 15 meters from the bridges.
- Old wheel and tread tracks in the road, with care taken to duplicate the track after mine emplacement.
- Underneath roads, tunneling in from the shoulders.
- Potholes in the road.
- Areas recently cleared by free world military forces. The enemy replaces the mines that have been taken out.

ANTIPERSONNEL MINES AND BOOBYTRAPS

Enemy tactics in emplacing antipersonnel mines and boobytraps differ from those used in antitank and antivehicular mining only by where they put them. Locations most commonly used by the VC/NVA to emplace antipersonnel mines and boobytraps are:

- Narrow passages.
- Paddy dikes.
- Trail junctions.
- Hedgerows and tree lines.
- Tunnels and caves.
- Fence lines and gates.
- Tree branches overhanging trails.
- Likely CP sites.
- High ground and ridgelines.
- Shady areas.
- Stream fords.
- Wells and natural watering points on streams and rivers.
- Likely helicopter landing zones.

➧ Remember: Any place a Marine frequently walks, takes cover, rests, or draws water is a likely location for enemy antipersonnel mines and boobytraps.

SECTION II

COUNTERMEASURES

Countermeasures are those actions, both tactical and nontactical, that can be taken by units and/or individual Marines which reduce the mine and boobytrap threat. Countermeasures decrease the enemy's ability to emplace mines and boobytraps or limit their effectiveness if they are emplaced.

NONTACTICAL COUNTERMEASURES

The most effective way to counter the enemy's mine and boobytrap threat is to destroy this threat at its source; i.e., the elimination of the VC/NVA mine and boobytrap factories and the sources of supply for these factories.

Every effort must be made to locate existing enemy mine and boobytrap factories and to determine likely locations for future factory sites. Hoi Chanhs, POW's and captured documents must be carefully processed because, with skillful handling, they provide vital information on factory location sites. Once found, existing factories and future locations must be made unusable.

More important than neutralizing the enemy's mine and boobytrap factories, is the denial to the enemy of the source of supply with which he operates these factories; i.e., unexploded U.S. ordnance, discarded equipment and improperly destroyed trash. The fact that U.S. ordnance and salvageable trash falls into enemy hands can be traced to several factors:

◊ Unexploded Ordnance

The first factor and an important source of unexploded ordnance for the enemy is provided by the free world military force's employment of air, artillery and naval gunfire support. Some ordnance items fail to detonate, become a "dud" and provide a potential mine or boobytrap. All Marines who employ fire support should consider this fact in the employment of supporting arms, and be careful not to call for fires in excess of what is required to accomplish the mission.

◊ Abandoned Munitions

The second factor, another important source of explosive materiel supply for the enemy's mine and boobytrap operations, is abandoned or lost munitions. The following examples, if allowed to occur, will assist the enemy in his efforts:

- Overstockage. A unit overstocks ammunition and then is required to move on short notice with only a basic load. The remaining ammunition is left on the abandoned position.

- Ammunition Handling Procedures. A unit attempts to turn in excess ammunition to an ASP (ammunition supply point) and is refused due to inefficient disposal procedures.

- Abuse of Ammunition. A unit discards ammunition considered unserviceable because of dirt, tarnish, mud or other avoidable conditions or minor imperfections.

- Loss in Transit. A helicopter sling breaks on an ammunition resupply mission and all or a portion of the load is scattered across the countryside.

Improperly Destroyed Trash

The last factor, but far from least important to the enemy's mine and booby-trap program, is his source of supply from friendly trash. All items considered unusable by free world forces must be completely destroyed or properly disposed of. Figure 2 shows one example of the results of an improperly policed friendly area of operations. Discarded C-ration/soda cans are also commonly used in a type of booby-trap which is constructed with an M26 grenade. The safety pin is removed and the grenade is put in the can. When the can is disturbed, the grenade slips out, the spoon pops and the grenade detonates.

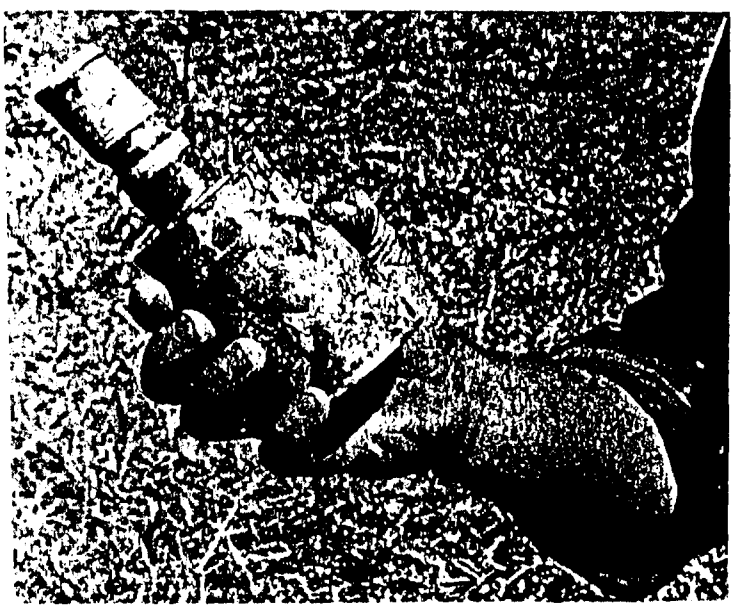


Figure 2.--Shown is a VC grenade made from locally available materials including a carelessly discarded "Coke" can.

******

The VIP (Volunteer Informant Program) has proved to be an increasingly effective countermeasure to the enemy's mine and boobytrap efforts. This program rewards Vietnamese individuals who turn in dud and abandoned munitions. Continued emphasis on this program will significantly decrease the enemy capacity to employ U.S. ordnance against free world forces. (See fig. 3.) During one period, 188 of 259 payments in the III MAF area were made to children who turned in explosives suitable for the manufacture of boobytraps. To ensure that the effectiveness of VIP reaches its full potential, it is the responsibility of every individual Marine and each Marine unit to give VIP their complete support.

Figure 3.--Shown here is the VIP (Volunteer Informant Program) in action. Articles on ground have been turned in to Marines by local villagers.

TACTICAL COUNTERMEASURES

Tactical countermeasures employed by Marine units are very effective in reducing the enemy's capability of emplacing mines or boobytraps if such countermeasures are aggressively planned and executed. Unit commanders have several tactical measures at their disposal, including the employment of sophisticated electronic devices. They are:

- Employing portable ground radar and seismic intrusion devices.
- Maintaining a constant physical presence throughout the TAOR to include outposting of key roads. This is the most effective tactical countermeasure, but sometimes difficult to achieve because of the number of Marines required to ensure good coverage.
- Conducting aggressive patrolling.
- Conducting reconnaissance patrols to verify S-2 intelligence reports.
- Employing scout-sniper teams.
- Conducting small unit cordon and search operations in coordination with Vietnamese units/police.
- Employing H&I fires over roads or over specific areas.
- Employing small stay-behind patrols dropped off unnoticed from units passing near a road.
- Paving or oiling dirt roads.
- Patrolling and outposting on and near roads.
- Employing Kit Carson Scouts. Using the native ability of the Kit Carson Scouts, coupled with their knowledge of the area of operations and VC activities, can prove highly useful in locating devices. During

October 1968, Kit Carson Scouts found 229 mines and boobytraps in the III MAF area.

• Scout Dogs. Using specially trained dogs (see fig. 4.) to detect the scent left by the individual emplacing a mine or boobytrap. This scent is detectable 1-4 days after emplacement. Since boobytraps are generally emplaced shortly after initiation of friendly operations, the chance of discovery by dogs is good. A trained dog will use his vision to detect tripwires and unnatural elements, and his hearing to detect sound waves created by tripwire vibration. Many dogs detect a tripwire when it touches the body hair of their forelegs or chest. Most are agile enough to back away before it is tripped. Of 119 dogs killed in SVN since January 1967, only seven were killed by boobytraps.

Figure 4.--Specially trained dogs such as the one shown here have proven extremely valuable in detecting enemy mines and boobytraps.

INDIVIDUAL COUNTERMEASURES

Individual countermeasures are those measures each and every Marine can take to diminish the effectiveness of a mine or boobytrap device which has been emplaced, and is found or is accidentally detonated. This can be accomplished through physical protective measures, detection and destruction measures, avoidance of explosive devices, and through application of immediate action when an explosive device has been accidentially detonated.

Physical Protective Countermeasures

The individual Marine can take these steps to reduce the effectiveness of enemy mines:

- Wear body armor and helmet.
- Sandbag vehicle flooring. When possible, place a heavy rubber mat over sandbags to reduce secondary fragments such as shrapnel, sand, stones and pieces of sandbag.
- Keep arms and legs inside vehicles to achieve maximum protection from sandbags.
- Maintain proper distance from other personnel.
- Don't travel alone.
- Don't pick up or touch what appear to be attractive "souvenirs". The VC/NVA prey upon the natural curiosity of Marines and their desire to take home a souvenir. Beware: That "souvenir" is most likely a boobytrap.

Detection Countermeasures

Once emplaced, a mine or boobytrap must be found before it causes multiple casualties through accidental detonation by

a Marine. Unfortunately, too many booby-traps are discovered only after they explode. It is imperative that detection techniques be stressed. Detection may be by:

- Visual inspection. At present, the best mine and boobytrap detector in the Marine Corps is an alert and observant Marine. Each Marine must know the areas in which boobytraps and mines are normally found and be alert for things which "just don't look right." Examples are:

  - Mud smears, mudballs, dung, or a board on the road.
  - Apparent road repair, new fill or paving patches, ditching or culvert work.
  - Wires leading away from the side of the road.
  - Tripwires across the trails; along shoulders of roads at likely ambush sites; across the most accessible route through dense vegetation; at fords, ditches and across rice paddy dikes.
  - Terrain features which do not appear natural. Cut vegetation dries and changes color; rain may wash away covering material and cause an explosive device to sink leaving a surface depression; a covered device may appear as a mound.
  - Suspicious items in trees, branches, or bushes.
  - Markings used by VC/NVA to indicate the location of a mine or boobytrap.

- Probing. Suspicious spots must be carefully probed with a probe or bayonet.

- Mine detectors. Mine detectors are designed to assist the individual Marine in a detailed, deliberate sweep of a specific area, usually a road. Particular

attention must be given to the time factors of the individual sweeping situation, since overhasty opening of a road can mean an ineffective sweep and quite possibly destruction or injury to vehicular traffic and personnel. The average sweep rate varies from almost nothing to about 5 m.p.h. depending, of course, on the proficiency of the team and the number of contacts encountered. In using detectors, certain considerations must be kept in mind:

- Graveled roads make it difficult for the AN/PRS-4 detector to discriminate between real and false targets.
- Metallic debris, such as can tops, small arms ammunition cases, and metal fragments from artillery rounds fired over roads at night to discourage mine laying, make it difficult for the AN/P153 detector to discriminate between real and false targets.
- The tendency for the enemy to bury mines deeper than designed detection depths, and to deliberately plant metallic debris in the road, calls for additional caution in the use of detectors.
- Operator fatigue. Consideration must be given to the fatigue experienced by operators after 20 minutes of wearing detector earphones. This condition can be delayed to 1 or 2 hours by wearing earphones over the helmet so that 2 to 4 inches exist between ear and phone. This also permits the operator to hear a verbal alert for an ambush.

- Use of the Buddy System. This system is not only useful in training inexperienced Marines, but also provides an extra margin of safety to the individuals who employ it. Two Marines working together, in the same area, have the advantage of

increased detection capability, mutual reassurance, and shared knowledge.

◊ Destruction Countermeasures

Once detected, mines and boobytraps must be marked and/or destroyed in place by the discovering person or unit to prevent accidential detonation by a following unit or individual Marine. Considerations for destruction are:

- Mines and boobytraps should not be moved unless absolutely necessary and then only by qualified EOD or engineer personnel. Many boobytraps are themselves boobytrapped, and if disturbed will detonate the associated device.
- Explosive devices should be destroyed by engineers. If engineers are not available, then devices may be destroyed by selected qualified personnel within each unit.
- Mines and boobytraps may be destroyed or neutralized by use of grappling hooks, demolitions, and artillery fires. The LVTE linecharge and the LVTE with plow-shaped mine excavator (figs. 5 and 6) should be considered for use in areas of high mine density.

◊ Avoidance Countermeasures

Strict application of training and careful planning of movements through danger areas will enable unit commanders and individuals to reduce casualties by simply avoiding the explosive devices. The unit leader must analyze from the enemy's viewpoint each area through which he intends to move his men. He must ask himself the question, "If I were the enemy, where would I put the boobytrap?" This question can and should influence both administrative

Figure 5.--The LVTE firing its organic linecharge to clear mines.

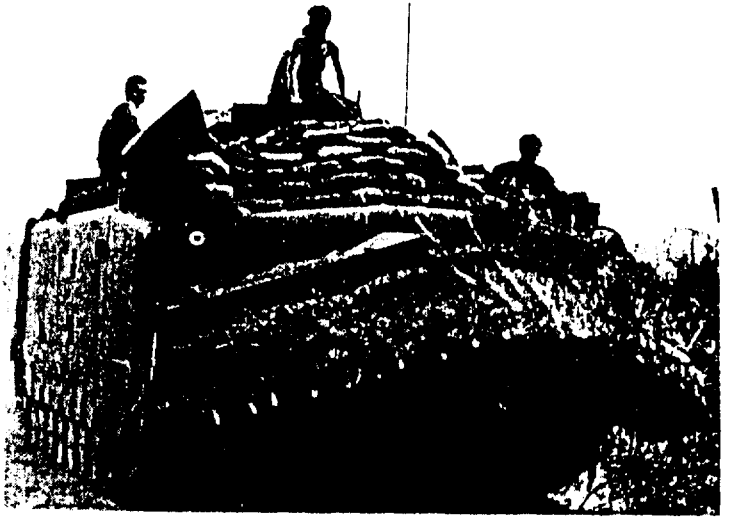


Figure 6.--The LVTE with its plow-shaped mine excavator.

and tactical movements and is a factor to be considered in the scheme of maneuver during an attack. Some suggested means for avoiding mines and boobytraps are:

- Stay off trails, footpaths, cart tracks, or other likely routes of travel as much as possible. Vary routes used to villages and key terrain features. Use of the same route twice is an invitation to the enemy to employ boobytraps. Keep the VC/NVA guessing as to which route will be used next.
- Move where local inhabitants move. These people know the location of most mines and boobytraps and will avoid these areas. In a village, stay near the villagers and watch which buildings they use. Use Vietnamese as guides whenever possible. Have sufficient money on hand to pay for information on mine and boobytrap locations and support VIP.
- Avoid patterns. Constantly change direction of movement. Check times of departure and return of patrols to ensure, for example, that all daylight patrols don't return before supper and all nighttime patrols depart after supper. Avoid the repeated use of the same bivouac areas.
- Maintain intervals of 15 meters between men and 100 meters between men and tracked vehicles. In view of the fact that the effective casualty radius of the M26 grenade is 15 meters, and that two or more casualties are suffered for each boobytrap grenade accidently detonated, the maintenance of proper interval is <u>most</u> important.
- Move slowly. Rapid movement generates carelessness. A unit must be allowed sufficient time to move to its objective.
- At times the enemy will show themselves only when they want to be seen. When

pursuing the enemy, be especially alert for deliberately emplaced boobytraps on the axis of advance.

- Artillery and mortar fires near and in the area of operations will not only discourage boobytrap emplacement, but will also neutralize devices by sympathetic detonation, overturning and burying emplaced mines, and rupturing tripwires. Employment of these fires beside a road, before and during a road sweep, will discourage command detonation of road mines.
- At all times, a lightweight stick (bamboo) or a slender steel rod can be helpful if used to feel for tripwires.
- Mark detected mines and boobytraps so those following may avoid them.
- Helicopters can be used to extract a unit which finds itself in a heavily boobytrapped area.
- At times, the flanks of a road are boobytrapped out to 250 meters as an obstacle to road sweep security teams. Tanks, preceding the infantry, can detonate these boobytraps. When trafficability permits, tanks moving off and parallel to the road sweeps can also reduce tank road-mining incidents. Random selection of tank travel between road and adjacent terrain will keep the NVA guessing as to the actual route the tank will take.
- When on roads, stay in the well-used portion and off shoulders.
- Follow the tracks of the vehicle ahead. If there is no vehicle ahead, stay out of the ruts.
- Avoid holes, depressions, and objects lying on the road.

➧ Remember: A boobytrap too easily detected can be a ruse resulting in detonation of other explosive devices emplaced nearby.

******

Immediate Action To Take When and After an Explosive Device Is Tripped

It is recognized that little reaction time exists once the detonation chain starts. The maximum delay for the M26 and foreign grenades ranges from 4 to 9 seconds. If the delay element has been modified, the minimum fuse delay can be less than 1 1/2 seconds. However, since the time available cannot be predicted, certain immediate action can assist in reducing casualties and the degree of personal injury.

◊ Immediate Action

FIRST: Be alert for the "pop" of the exploding cap, the tug of the tripwire, or the warning of another Marine.

SECOND: Sound a warning so that others may take cover.

THIRD: Drop to the ground immediately.

Immediate action is designed as an instinctive reaction based on minimum fuse delay. When using it also remember:

- Do not attempt to outrun the explosion. The 800 fragments of the M26 grenade have an initial velocity of over 5000 feet per second. During the available delay, however brief, an individual can best remove himself from the cone of the explosion by dropping to the ground. He must assume a minimum delay in every case.
- If possible, when dropping to the ground, present the smallest target to the force of the explosion by pointing the feet in the direction of the charge.
- All those nearby should drop to the ground when the warning is sounded.

- Do not immediately rush to the aid of Marines wounded by mines or boobytraps. Frequently there is a second boobytrap in the vicinity of the first. The man nearest each casualty should carefully clear his way to the wounded individual and render first aid. Under no circumstances should the unit leaders or others crowd near the wounded men.
- Conduct a brief but careful search for other explosive devices in the immediate vicinity before moving on.
- If a device is tripped and does not explode, follow the same immediate action and then blow it in place.

******

UNIT TRAINING

We have discussed preventive countermeasures, tactical countermeasures and individual countermeasures. Simply realizing that these countermeasures exist isn't sufficient. It is imperative that every Marine becomes knowledgeable of and proficient in the execution of the countermeasures discussed. This task can be accomplished through an aggressive and comprehensive unit and individual training program. Such training should emphasize:

- Wearing of helmets and body armor.
- Dispersion between men.
- Alertness.
- Visual detection techniques.
- Operation of electronic detection equipment.
- Demolition training which enables Marines to destroy explosive devices in place.
- Employment of the buddy system.
- Avoidance of patterns.
- Immediate action procedures and action to take subsequent to the detonation of an explosive device.

SECTION III

ENEMY MINE INDICATORS

If the enemy emplaces mines or booby-traps in the vicinity of villages or in areas where he moves or expects to move, he often indicates the location or direction of the explosive devices in some manner. The VC/NVA may not always follow the examples in this publication in absolute detail, but as a general rule, the indicators are usually found in a regular pattern such as sticks or stones in a line or sticks placed on or in the ground. This regularity of pattern is the danger signal (see fig. 7). Any arrangement of sticks and stones which appears unnatural indicates a strong possibility of the presence of

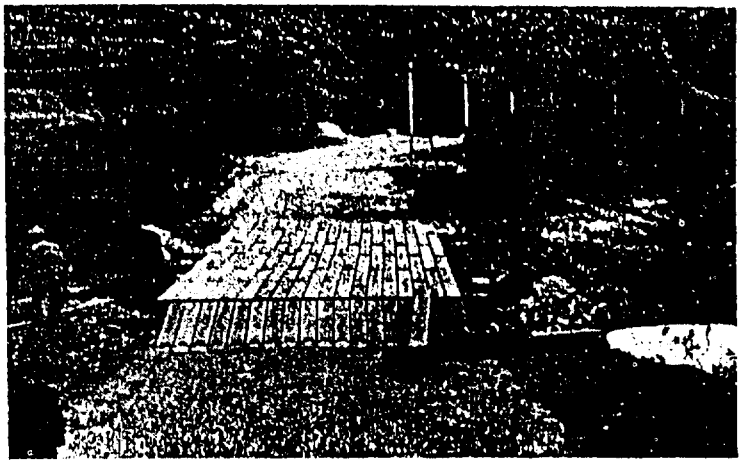
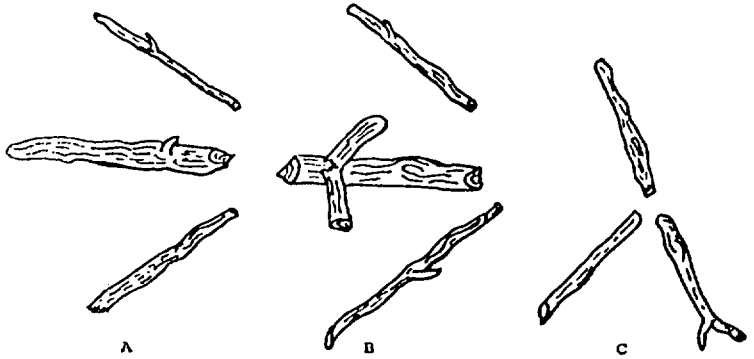


Figure 7.--Note the row of rocks on top of bridge beam at the foot of the bridge. This is typical of the warning signs used by the VC/NVA to warn of their mining activities.

mines and boobytraps. The illustrations which follow are examples of marking patterns indicating the presence of mines and boobytraps which have been encountered thus far in SVN.

ARROW MARKERS

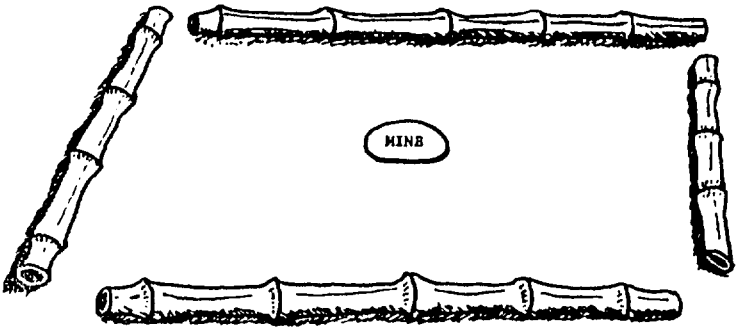


A. Three sticks are placed on the trail in the form of an arrowhead. The important thing to remember is that the point of the arrow does not always point in the direction of the boobytrap. The symbol can only be considered as a means to identify an area as being boobytrapped.

B. A variation of the three-stick arrowhead shows a fourth stick. Again, no definite pattern has been established as to direction or the reason for the fourth stick (usually broken). But it does mean boobytraps in the area.

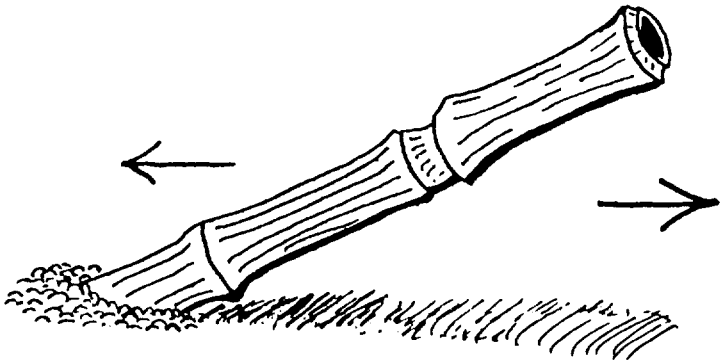
C. The "Y" arrangement is sometimes found farther down the trail from the arrowhead indicating the limit of the danger area. No pattern or specific distance has been established.

BAMBOO RECTANGLE MARKER



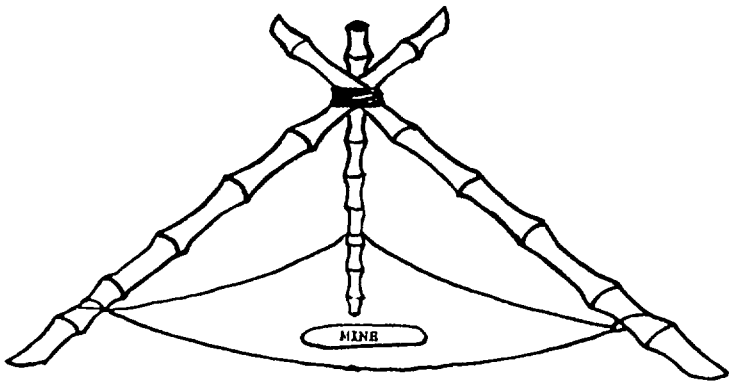
As shown, this marker usually indicates a boobytrap within the square. Most of these symbols found have been laid out with bamboo 18 to 42 inches in length.

BAMBOO MARKER



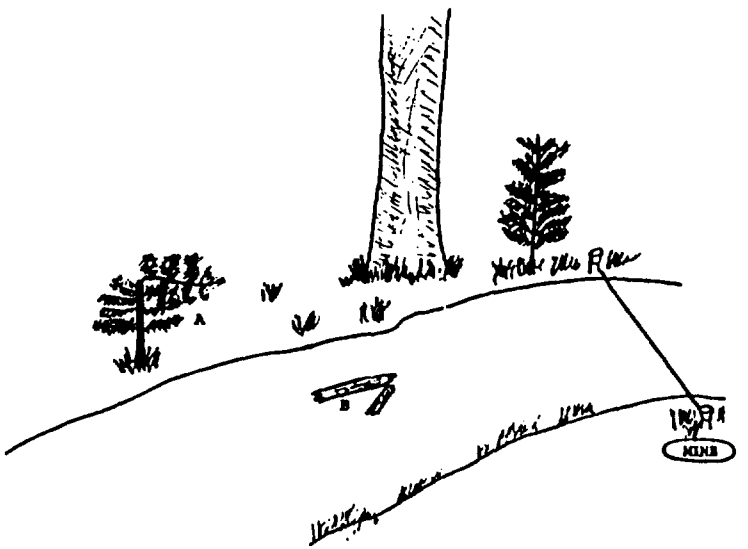
A piece of bamboo 6 to 8 inches long is stuck in the ground at an angle of 45 degrees. Generally, boobytraps can be expected along the axis of the bamboo in either direction.

BAMBOO TRIPOD MARKER



The bamboo tripod consists of bamboo, usually about 18 inches long, tied together to form a tripod. Wire, vines, cord or string is wrapped around the legs near the bottom to hold the tripod in place. This device has been found directly over punji pits, boobytraps, and mines.

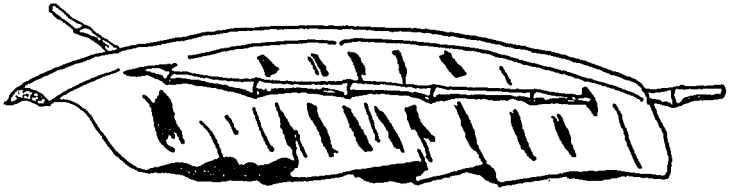
BROKEN BUSH OR STICK MARKERS



A. The enemy has been known to break the tops of small saplings and bushes pointing the broken part in the direction of the boobytrapped area. Usually mines and boobytraps are planted 50 to 100 meters from this marker.

B. A stick or length of bamboo broken at a right angle and lying across the road or trail may mean an enemy mine or boobytrap 200 to 400 meters ahead.

BANANA LEAF MARKERS

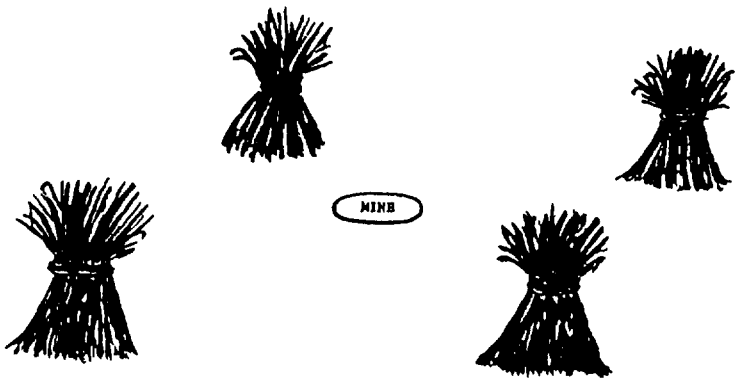


A banana leaf or other similar leaf is folded down the center with a thin stick approximately the thickness of a toothpick woven through in two places. In addition to marking mines, this may indicate an ambush area. There is no pattern as to location or distance of mines or ambushes from this marker.

PARALLEL STICK MARKER

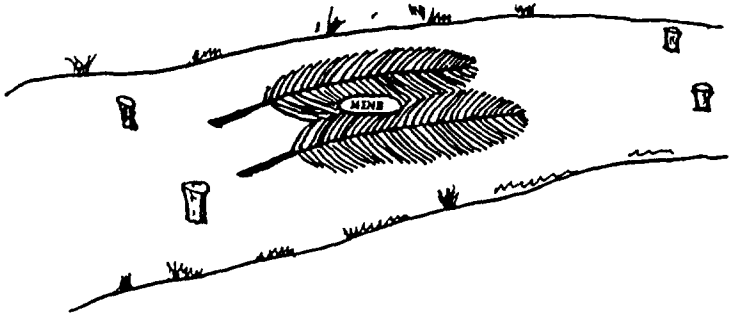
Short sticks or lengths of bamboo laid parallel to a road or trail usually mean the road or trail is free of mines or boobytraps.

GROWING GRASS MARKER



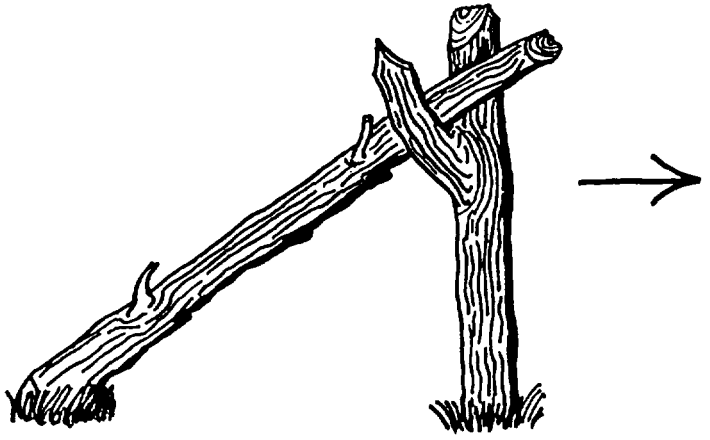
Growing grass is sometimes tied to form four growing sheaves of grass. The tied sheaves form a square of about 6 feet. The mine is buried or concealed in the center of the square.

TRAIL MARKERS



These devices have been used extensively together. The mine or boobytrap is placed (buried) under two large leaves. In front and to the rear, at no special distance, stakes are driven. The markers have also been used independently of each other at times.

FORKED-STICK MARKER

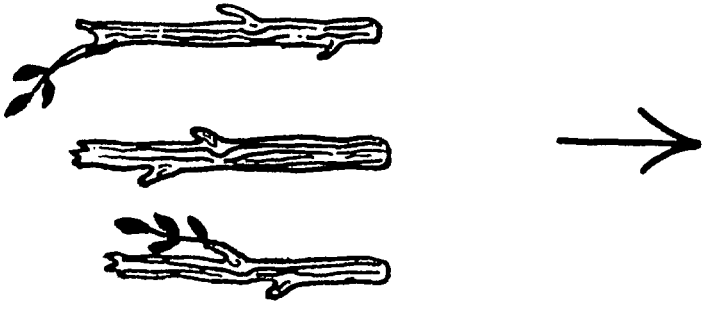


A forked stick is driven vertically into the ground and another stick is laid into the fork with the elevated end pointing to the danger area. Distance to explosive device is unknown. This sign may also indicate enemy direction of movement.

ROCK MARKERS

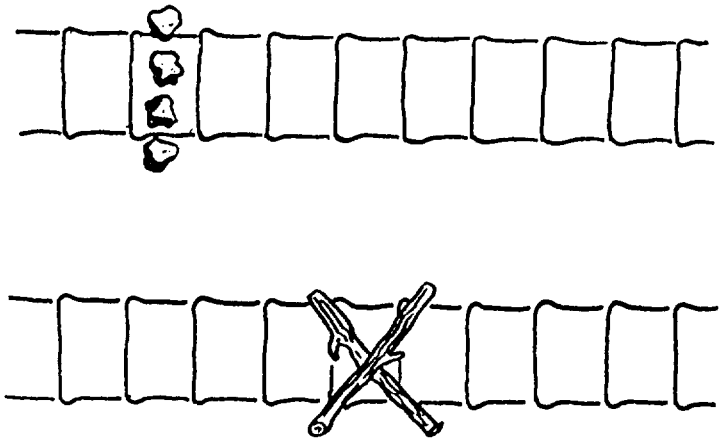
Various formations of rocks and small stones are used to mark boobytrapped areas. No pattern of distance or location has been established.

SPACED-STICK MARKER



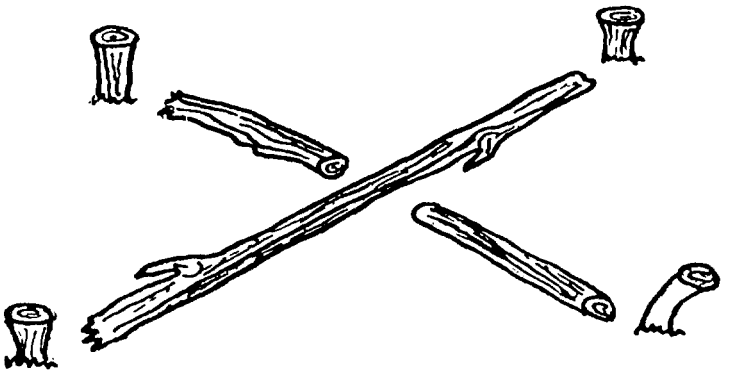
Three sticks, one on each side of a road or trail and one in the middle, usually mean the road is not to be used. A mine or boobytrap is usually 200 to 400 meters from the marker. Stones have been used in the same manner.

TRACK MARKER



The enemy has capitalized on our habit of following old vehicle tracks by placing mines in these tracks. Mines are sometimes marked with crossed sticks or an arrangement of stones. The location of the mine in relation to these markers is unknown. The mine may be under the marker or up to 400 meters farther on.

STAKES WITH X-MARKER



An M1A1 antitank mine with approximately 25 pounds of TNT was discovered under this marker. The mine had been marked with stakes at each corner and three sticks forming an "X" over the mine.

SECTION IV

ENEMY MINES AND BOOBYTRAPS

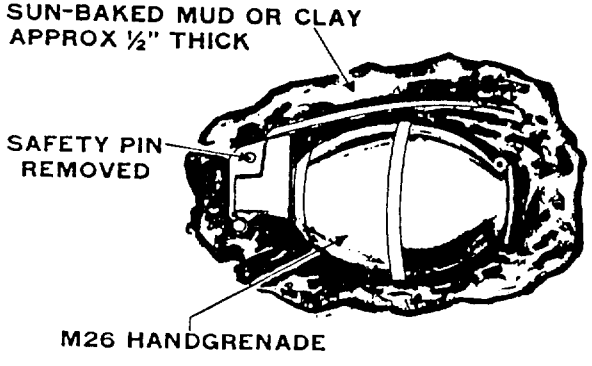
EXPLOSIVE ANTIPERSONNEL DEVICES

Mines and explosive boobytraps employed by the enemy against friendly personnel are limited in type and quantity only by the availability of explosive materials and the imagination of the enemy. Anything that can be made to explode and cause injury can be rigged as an antipersonnel mine or boobytrap.

Antipersonnel mines and explosive boobytraps are very successfully employed by the VC/NVA. Part of this success is because Marines are not familiar with the physical description of explosive devices normally employed by the VC/NVA, and thus fail to recognize them prior to accidental detonation.

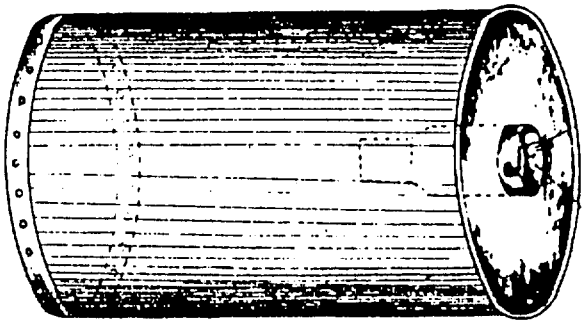
The following illustrations represent some of the devices employed by the VC/NVA in SVN.

MUDBALL MINE



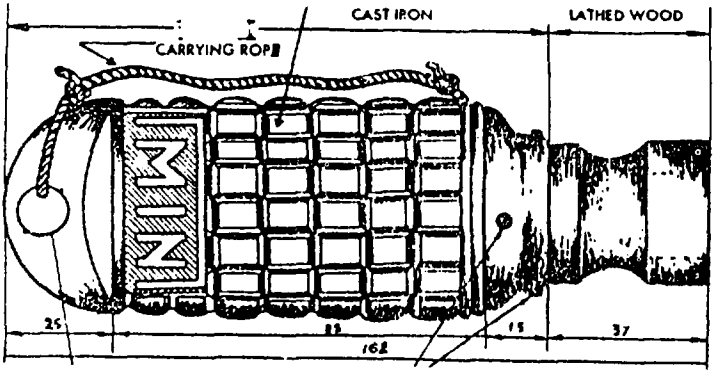
The mudball mine consists of a hand-grenade encased in sun-baked mud or clay. The safety pin (pull ring) is removed and mud is molded around the grenade. After the mud dries it holds the lever of the grenade in the safe position. The mudball is placed on trails or anywhere troops may walk. Stepping on the ball breaks the dried mud apart and releases the lever detonating the grenade. The U.S. M26 and M33 handgrenades have been the most commonly used grenades for this purpose although other lever-type grenades may be used.

TIN CAN ANTIPERSONNEL MINE



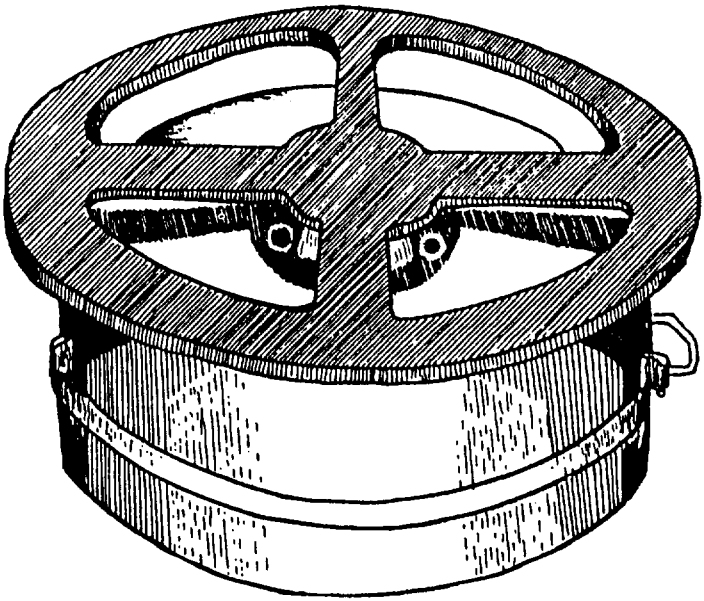
The tin can mine is constructed from sheet metal or any discarded metal container (C-ration, beer, or soft drink can). The firing device for the explosive is an improvised fuse with zero delay action. A handgrenade fuse may be used by removal of the delay element. The mine functions by a tripwire attached to the pull ring. Pressure on the tripwire pulls the pull ring, activating the mine in the same manner as a handgrenade.

CAST-IRON ANTIPERSONNEL FRAGMENTATION MINE



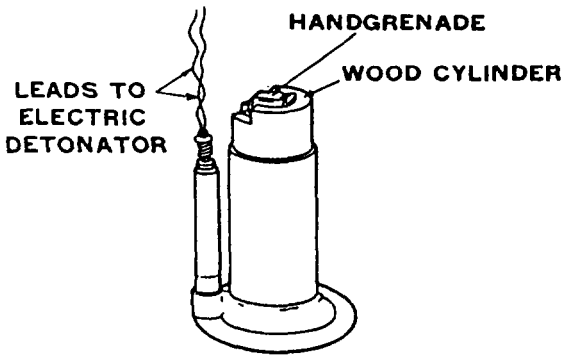
This mine, made of cast iron, resembles a stick handgrenade with a very short handle. The word "MIN" is often found cast into the body. The handle houses a pull-friction igniter. A tug on a trip-wire attached to the friction igniter will activate the fuse.

CHINESE COMMUNIST NO. 8 DUAL-PURPOSE MINE



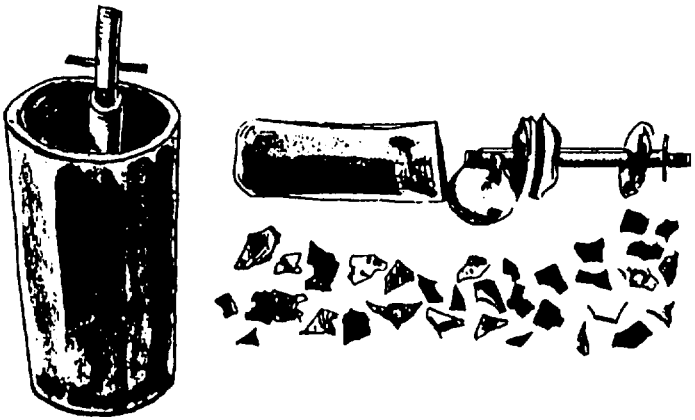
Almost identical to the CHICOM No. 4 Dual-Purpose Mine, this device also has a double-acting fuse. Like the No.4, a pressure of 300 pounds on the pressure spider or a pull of 10 pounds on an attached tripwire will detonate the mine. Slightly larger than the No.4, this mine contains 5 pounds of explosive and has an overall weight of 12 pounds. It is made of metal and coated with creosote for waterproofing.

BOUNDING FRAGMENTATION MINE



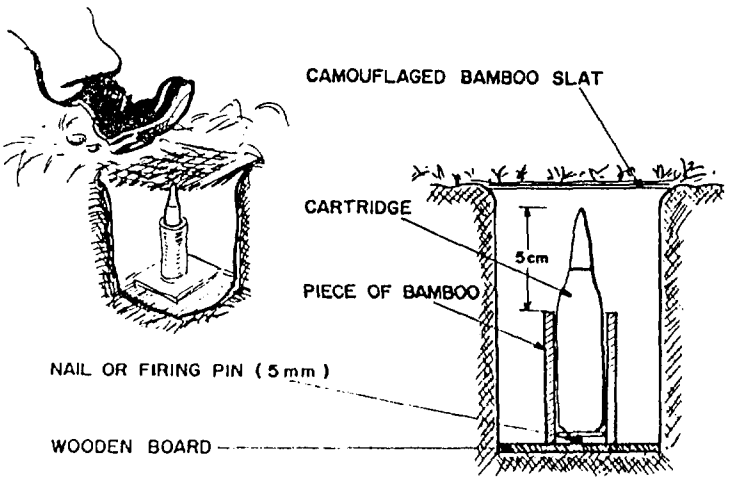
The bounding mine is improvised from expended U.S. M2 bounding mine or M48 trip-flare cases. A wooden cylinder slightly smaller in diameter than the mine case is hollowed out so that a standard grenade can fit inside. The wooden cylinder (with enclosed grenade) is then fitted into the mine case and the grenade's safety pin is extracted. When the mine is detonated, the cylinder and grenade are propelled upward. As the wooden cylinder and grenade separate, the handle flies off the grenade, activating the fuse.

VC "TOE POPPER" MINE



This mine is fabricated of cartridge cases or pieces of pipe of various sizes. It is loaded with a charge of black powder, a primer, and a variety of fragments for missile effect. When the victim steps on the mine, the igniter detonates the black powder charge and propels the fragments upward.

CARTRIDGE TRAP

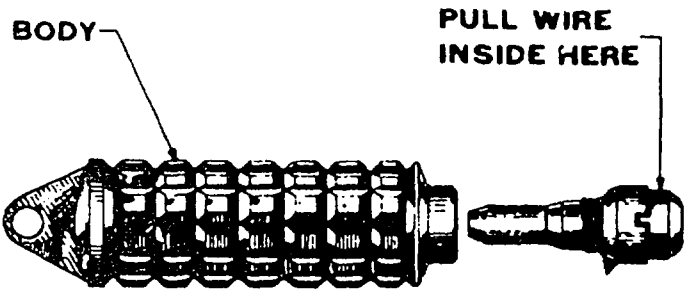


Four simple and easily obtainable components make up this mine; a bamboo tube, a nail, a piece of wood, and any small arms ammunition or M79 round. The piece of wood is used as a base. The bamboo tube is placed upright on the wooden base and a nail is driven up through the wood to penetrate the bottom of the bamboo. The cartridge is then wedged into the bamboo so that the primer is touching the point of the nail. Partially buried along a trail or path, the pressure of a man's foot stepping on the nose of the cartridge forces the primer onto the nail, firing the cartridge.

DIRECTIONAL FRAGMENTATION MINE (DH-10)

Commonly referred to as a "CHICOM or VC claymore," this mine has characteristics similar to the U.S. M18 Claymore Mine. Fused electrically, it is a command-detonating device designed for employment from ambush or defensive positions. It has a range of 150 to 200 meters and is effective against personnel and thin-skinned vehicles.

POMZ-2 ANTIPERSONNEL MINE



Chinese Communist copies of the Soviet POMZ-2 mine are now being employed by the VC/NVA. Weighing only 4.4 pounds, it is easily carried and can be emplaced quickly. Fused for detonation by tripwire (tension release or pressure release), it can also be rigged electrically for command detonation.

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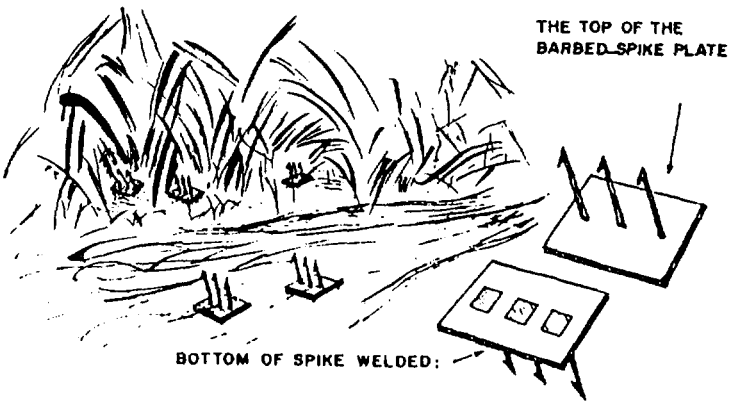
NONEXPLOSIVE BOOBYTRAPS

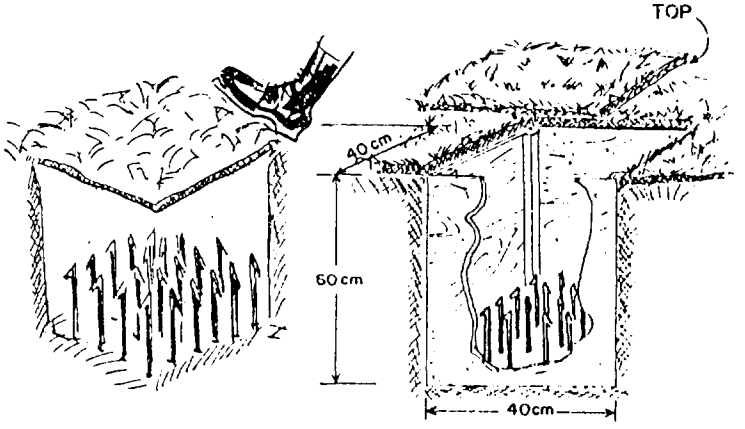
The idea of nonexplosive boobytraps is as old as man. From the simple earth pit lined with sharpened stakes to highly sophisticated mechanisms of triggered coils and latches, the enemy employs them all. The principle employed is simply to use anything that will catch the victim by surprise.

BARBED-SPIKE PLATE



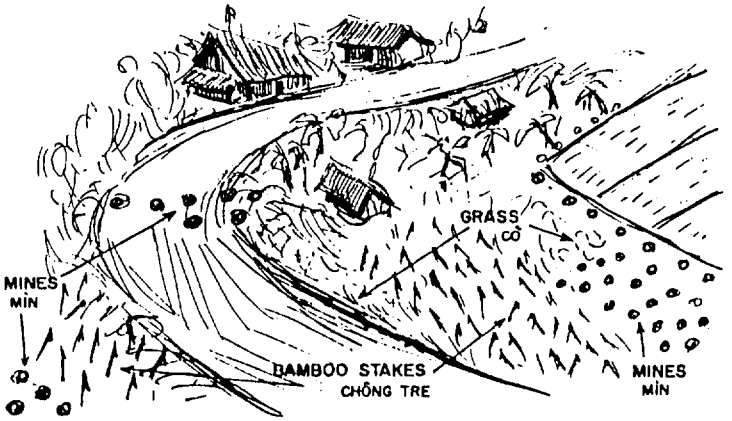
The barbed-spike plate is the basic element of all enemy nonexplosive booby-traps. The plate, a flat piece of wood or metal, is used as a base to fasten any number of barbed spikes. The spikes, ranging in length from several inches to several feet, are fastened securely to the base. When a man steps or falls on the spiked plate, or is struck by one, the spikes will penetrate, producing a serious wound.

SPIKE TRAP BOX



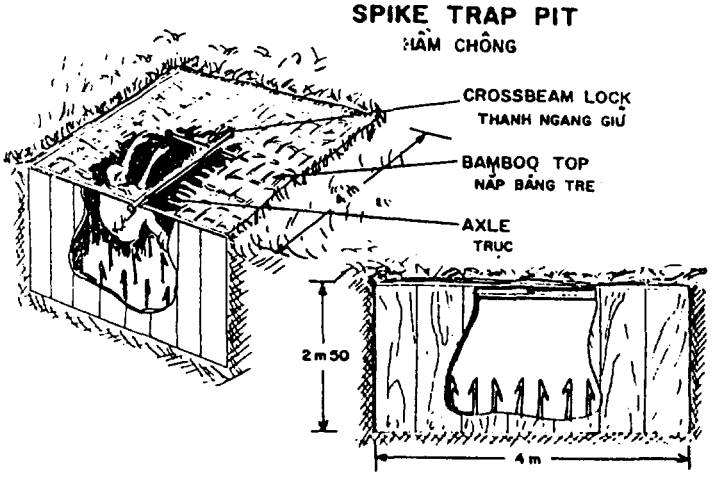
This device is a simple wooden box made of boards joined together with four corner posts. The box has a lightweight top but the bottom is removed. Barbed spikes are placed in the ground at the bottom pointing upward. This trap is usually set up on dirt roads and trails to take advantage of favorable camouflage.

POINTED BAMBOO STAKES



Made of bamboo which has been sharpened, the stakes are stuck in the ground and covered with grass. When a weapon is fired or a grenade thrown, troops seek cover and are impaled.

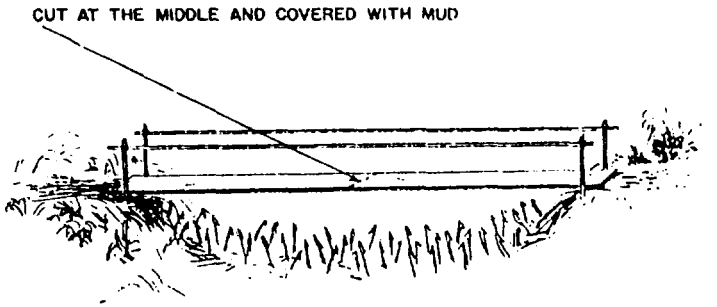
SPIKE TRAP PIT



A trap pit is a large trap box with a bamboo top. Stakes are made of sharpened bamboo or barbed spikes and used to line the box. When a man steps on the trap he will fall into the pit. The top turns on an axle; therefore, the trap does not need to be reset to work again. The pit is often prepared as a defensive obstacle and then made safe by locking it in place with a crossbeam (so it can be crossed safely by the enemy) until the desired time of use.

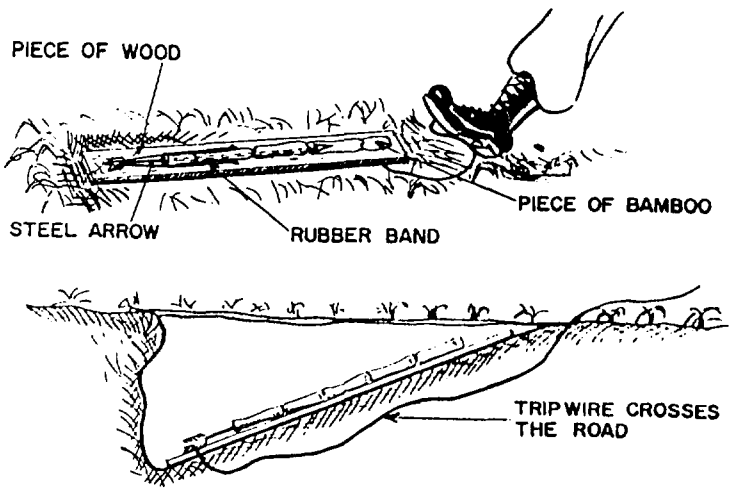
TRAP BRIDGE

TRAP BRIDGE



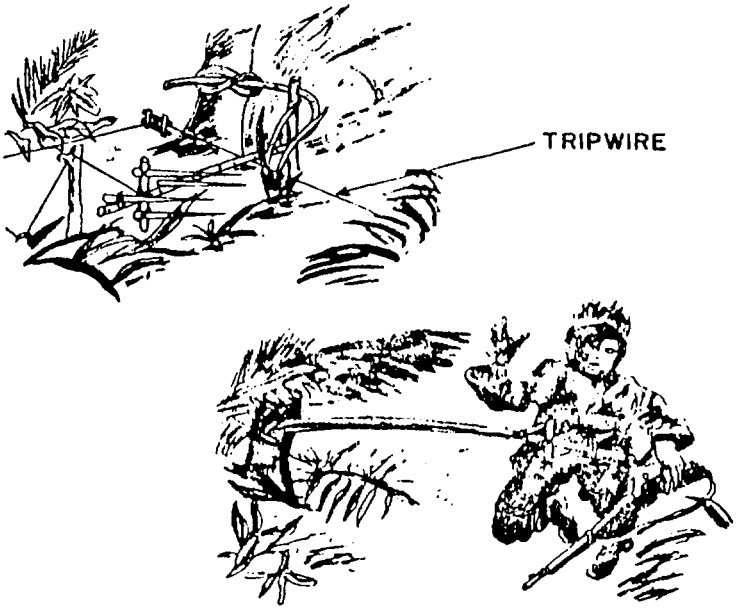
A small footbridge is partially cut in the middle. The cut is then camouflaged with coverings of mud, etc. Barbed spikes or sharpened bamboo stakes are emplaced under the cut, using the water, mud or foilage under the bridge as camouflage. The weight of a man on the bridge will cause it to collapse, tumbling the victim onto the spikes. Like the spike trap pit, bridges can be prepared in this manner, then braced for normal use. At the approach of free world forces the braces are removed.

STEEL ARROW TRAP



This trap utilizes a bamboo tube (usually about 3 feet long) as a launcher. A steel arrow is placed in the tube. Using a block of wood as the bolt, a strip of strong rubber for power and a catch to lock the rubber strip, the device is fired with a tripwire. When the victim trips the wire, the latch disengages, allowing the rubber strip to launch the arrow.

BAMBOO WHIP



A strip of springy bamboo from 3 to 10 feet in length is used to make a bamboo whip. A barbed-spike plate is secured to the tip of the bamboo (or several of the spikes driven through the bamboo), and the whip is drawn back and secured. A tripwire is then latched to the whip and the wire is strung across the trail. When a man trips the wire, the bamboo is released, and whips around, striking the victim with the spikes.

ANTITANK AND VEHICLE MINES

Mines employed by the enemy against wheeled and tracked vehicles vary from conventional antitank mines of foreign manufacture to rigged duds and locally produced explosive devices. All the industrially produced mines are of the type fused for detonation at from 150 to 400 pounds of pressure. They are buried slightly beneath the surface of the ground. The enemy generally employs these mines as designed but has varied fusing and positioning so that there is no definite pattern.

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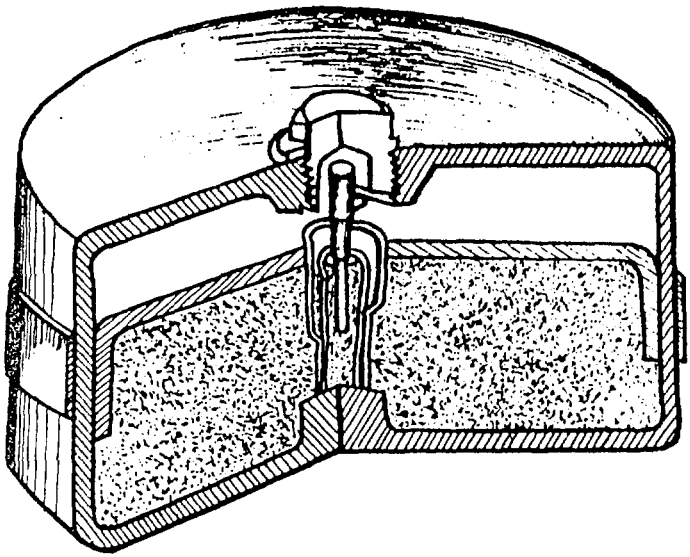
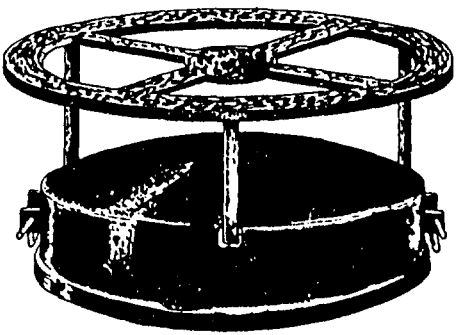
SOVIET ANTITANK MINE TMB-2



Designed to avoid detection by a mine detector, this mine is constructed of black or brown tar-impregnated cardboard. It is gauged for activation by a force of 350

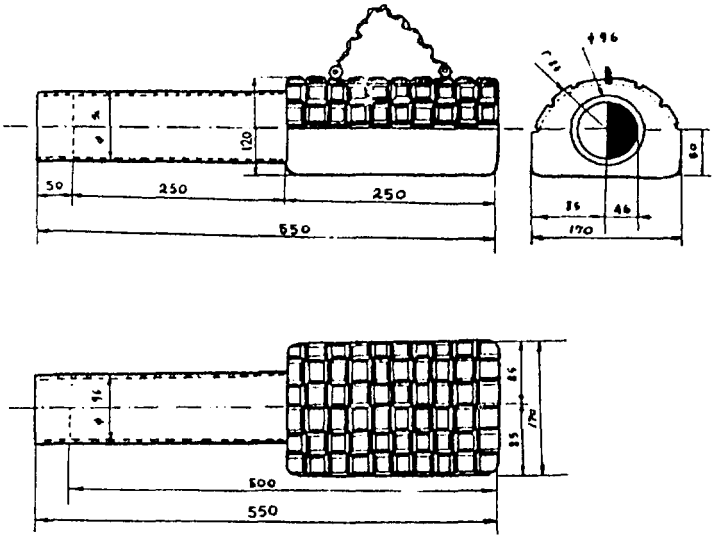
pounds of pressure. Further, it can be waterproofed by use of wood and plastic sheeting, without losing its nondetection characteristic. It contains 11 pounds of explosive and has an overall weight of 15.4 pounds.

CHINESE COMMUNIST NO. 4 DUAL-PURPOSE MINE



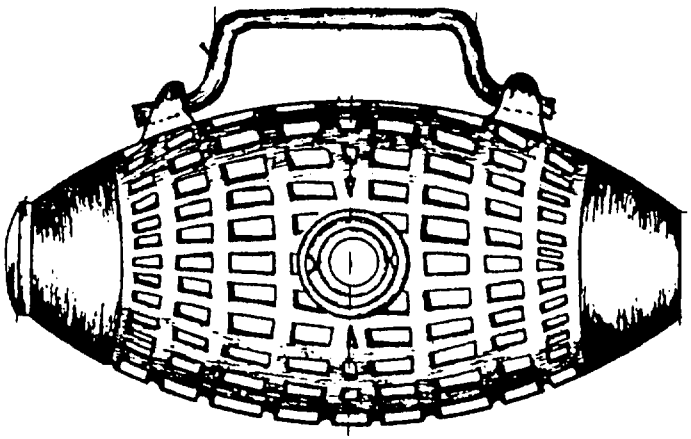
Intended for employment against both vehicles and personnel, this mine incorporates a double-acting fuse that will detonate the mine under either of two circumstances: The first, when a load of 300 pounds of pressure is applied to the pressure spider; the second, when a pull of 10 pounds is exerted on a tripwire fastened to the fuse's striker-retainer pin. Constructed of creosoted metal, it carries 4 pounds of explosive and has an overall weight of about 10 pounds.

CONCRETE FRAGMENTATION MINE



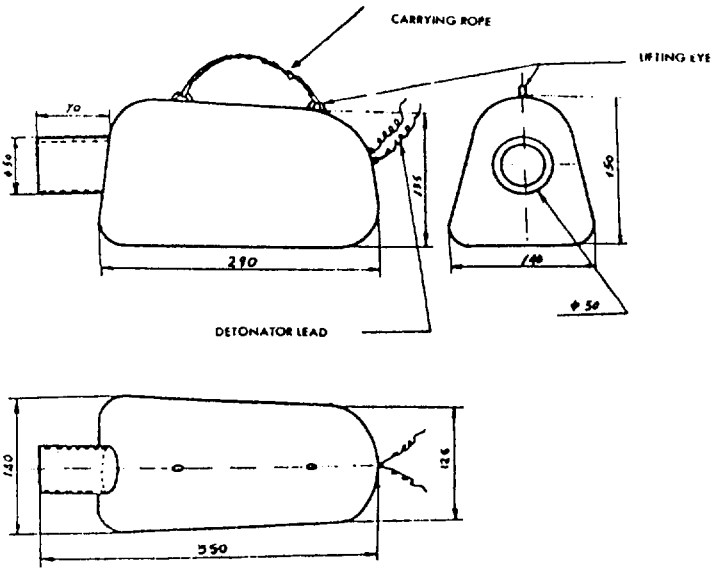
This mine is constructed of explosive encased in a cylindrically shaped concrete shell with a flat side for stable emplacement. A 2-inch-diameter pipe on one end of the mine serves as a carrying handle and detonator housing. The two swivels on top of the mine are used to tie it to an object. Usually employed as a command-detonating mine, it is equipped with an electrical firing device.

NVA CAST-IRON FRAGMENTATION
ANTITANK MINE



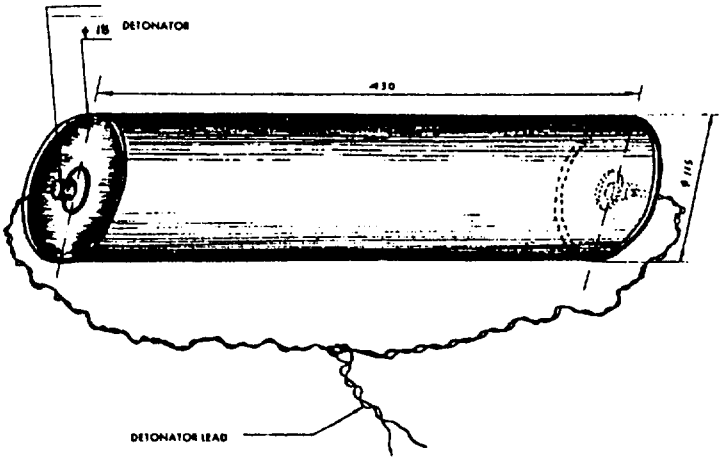
Produced in North Vietnam, this egg-shaped mine is made of cast iron with serrations on its outer surface. Designed for command detonation, the mine is fused with an electrical detonator and weighs 12 pounds.

VC MOUND-SHAPED MINE



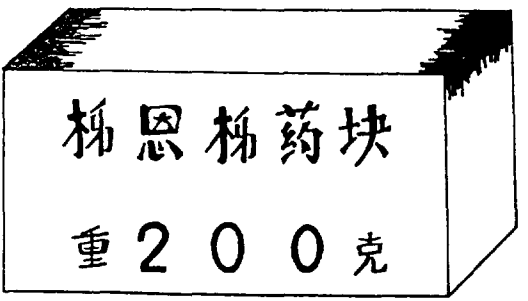
Manufactured locally in VC mine factories, this mine contains an iron-pipe detonator encased in concrete. Another command-detonating mine, it is fused electrically and weighs 13 pounds.

VC ROUND VOLUME MINE



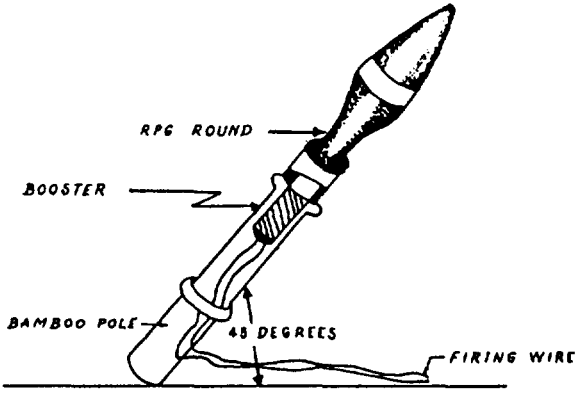
Produced locally in VC mine factories, this mine is a prototype of numerous other VC-manufactured explosive devices. Constructed of sheet metal, with welded seams, it generally weighs about 15 pounds, of which 13 pounds are explosive. Command detonated, it is fused electrically and employs two detonators, one in each end of the mine. The same principle of construction is applied to salvaged artillery shell casings, expended LAAW launchers, and most other devices using metal containers.

VC BOX MINE AND DEMOLITIONS



The VC box mine is constructed of wood utilizing discarded ammunition boxes or any scrap material. Mine detectors will not locate these devices. They can be waterproofed with plastic sheeting. Box mines are produced in various sizes but the most common contains about 40 pounds of explosive. The mine can be fused for command detonation or self-detonation by the use of various devices. The explosive charge is usually made up of standard Soviet or Chinese Communist 1-pound demolition blocks.

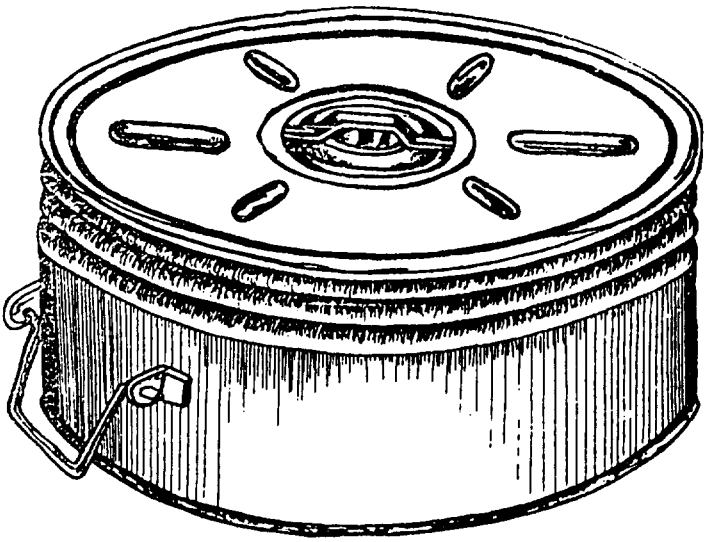
B-40 ANTITANK BOOBYTRAP



ANTITANK BOOBYTRAP

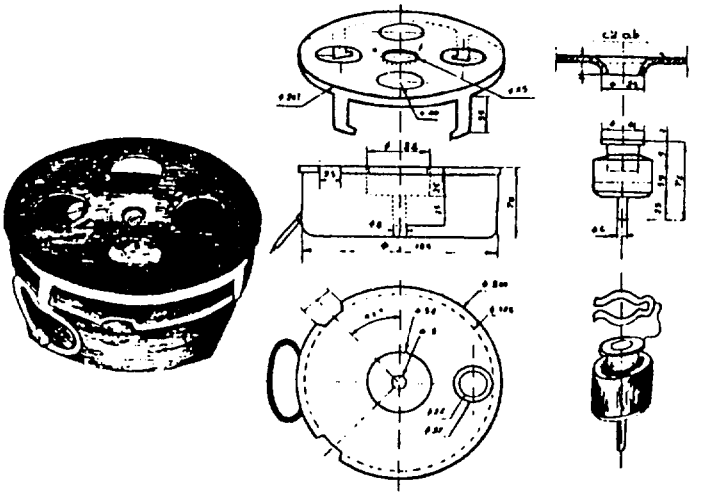
A length of bamboo is emplaced at an angle of 45 degrees along the shoulder of a road. A B-40 rocket is then placed in the bamboo tube and fired electrically by command detonation as the tank or vehicle crosses the line of fire.

SOVIET ANTITANK MINE TM-41



Constructed of blued steel, sometimes painted olive drab or white, the TM-41 carries an explosive charge of 8 pounds and has a total weight of 12 pounds. A force of 350 pounds of pressure on the lid will activate the firing device. With very little additional waterproofing it can remain operational indefinitely.

CHINESE COMMUNIST M1A1 ANTITANK MINE



Manufactured in Communist China, this mine is similar to and often mistaken for a U.S. pre-World War II mine. Made of metal, it is painted olive drab with the yellow markings "MINE M1A1-TNT". It is activated by 200 pounds of pressure on the pressure plate. This mine contains 4 pounds of explosive and weighs 11.5 pounds.

ANTIHELICOPTER MINING

The degree of success that the employment of helicopters has had on restricting and containing VC/NVA activities is evidenced by the enemy's efforts to destroy or neutralize these machines. In addition to intense ground fire, the enemy has devised numerous helicopter landing zone destruction systems. Such destruction systems range from the primitive planting of long pointed stakes to imaginative explosive devices. Because of its design, the helicopter is extremely vulnerable to these devices, particulary the rotors and airframe.

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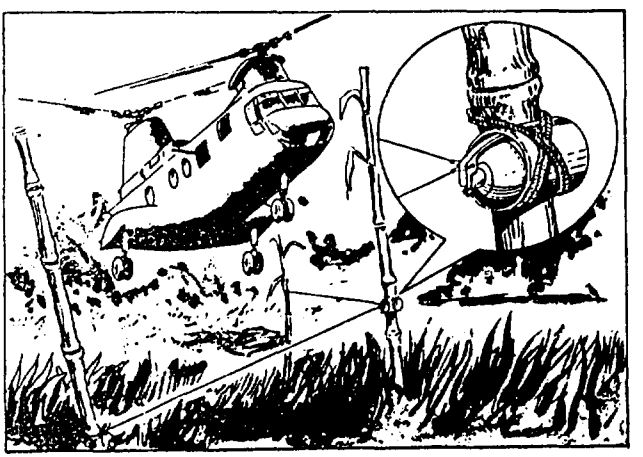
HELICOPTER EXPLOSIVE TRAPS



Grenades, artillery/mortar rounds, or any other type of exploding ordnance are mounted in trees or on the surface of the landing zone. The explosive devices are rigged for tripwire detonation and the

wire is strung to loosely emplaced poles. The rotorwash of landing helicopters will blow the poles from their loose position, tripping the device.

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A 13-year-old Vietnamese boy recently claimed that the VC had forced him to reconnoiter helicopter landing zones. The boy was instructed by the VC to place handgrenades in the zones with strings wrapped around the levers, pieces of paper attached to the free ends of the strings and the rings (pull rings) pulled. Rotorwash from landing helicopters would then blow the paper, unwrap the string, and release the safety lever.

TM 31—201—1

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

UNCONVENTIONAL WARFARE DEVICES AND TECHNIQUES

INCENDIARIES

HEADQUARTERS, DEPARTMENT OF THE ARMY
MAY 1966

TECHNICAL MANUAL
No. 31-201-1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *20 May 1966*

Unconventional Warfare Devices and Techniques

INCENDIARIES

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CHAPTER 1
INTRODUCTION

0001. INCENDIARY SYSTEMS

a. This manual covers all aspects of incendiary systems. It describes useful initiators, igniters, incendiary materials, delay mechanisms, and spontaneous combustion devices designed for direct use in sabotage and unconventional warfare.

b. Incendiaries are primarily used in sabotage to set fire to wooden structures and other combustible targets. Certain incendiaries, such as thermite, can be used for melting, cutting, or welding metals.

c. The most basic incendiary system consists of putting a lighted match to an easily combustible material. However, a simple match is not always effective. There are many important combustible targets that require far more heat for reliable ignition than is available from a match. There are also instances where delayed ignition is essential for sabotage success. This manual contains formulations and devices to satisfy the requirements for high ignition heat and predetermined ignition delay times for use in sabotage and other harassment actions.

d. Every incendiary system consists of a group of elements starting with an initiator and ending with the main incendiary material. If the initiator does not produce enough heat for reliable ignition of the combustible target, an intermediate or booster incendiary is required. More than one booster is necessary for some targets. The initiator (ch 2) can consist of a simple match, a match and a fuse cord, an acid, or water. The intermediate heat sources are generally called igniters (ch 3). Igniters produce sufficient heat to set the principal incendiary charge (ch 4) aflame. Delay mechanisms (ch 5) are frequently used to prevent detection of the saboteur by postponement of the fire for some limited, predetermined time after placement and actuation of the device.

e. Spontaneous combuston is a good sabotage tool. Favorable conditions can be established for the deliberate employment of spontaneous combustion (ch 6), that is, setting combustible material aflame without application of direct flame or spark.

f. All of the devices and techniques described herein have been thoroughly checked by independent test to

make certain that they work as intended. Detailed instructions are given for the necessary ingredients and their preparation. It is important that these instructions be followed carefully to be sure that the devices will operate properly. In addition, close attention to the instructions will assure safety.

0002. DEFINITIONS

Common terms used in connection with incendiary systems are defined below. Note that the definitions are worded so as to cover only incendiaries. Some of the terms have additional meanings in the related field of explosives.

a. Delay Mechanism. Chemical, electrical, or mechanical elements that provide a time delay. Elements may be used singly or in combination. They provide a predetermined, limited time interval before an incendiary starts to burn.

b. Fuse. A flexible fabric tube containing powder that is used to start fires at some remote location. The powder in the fuse burns and provides a time delay.

c. Igniter. An intermediate charge between an initiator and an incendiary material. It is set aflame by the initiator and produces sufficient heat at high temperature to ignite the main incendiary. Igniters are fast burning and relatively short lived.

d. Incendiary Material. A material that burns with a hot flame for long periods. Its purpose is to set fire to wooden structures and other combustible targets.

e. Incendiary System. A group of elements that are assembled to start fires. The system consists of initiator, delay mechanism (if needed), igniter, and incendiary material.

f. Initiator. The source that provides the first fire in an incendiary system. A match is an initiator. The initiator is so sensitive that it can be set off with little energy.

g. Spontaneous Combustion. The outbreak of fire in combustible material that occurs without an application of direct spark or flame. The fire is the result of heat produced by the chemical action of certain oils.

h. Thermite. An incendiary mixture of iron oxide flakes and aluminum powder that reacts chemically when initiated to form molten iron. Thermite can be used to burn holes in steel or to weld steel parts together.

0003. TOOLS AND TECHNIQUES

a. The equipment needed for the manufacture of incendiaries consists of simple items. They are all readily available. Required are bottles, jars, pots, and spoons. There should be no difficulty in obtaining any of them. All of the necessary equipment is described in each paragraph dealing with a particular incendiary component.

b. It is important that the operator follow the directions given in this manual *exactly* as written. They have been worked out carefully to give the desired results with the minimum chance of mishap. Don't experiment with different procedures or quantities.

c. By its very nature, the manufacture of incendiaries is dangerous. It is the function of incendiaries to burn with an intense flame under the right conditions. Care must be taken that no fires result during the making or placing of the devices. There are also other dangers in addition to the fire hazard. The chemicals used as ingredients may burn the skin, give off poisonous fumes, or be easily flammable. They must not be eaten.

d. When handled with care and proper precautions, incendiaries are fairly safe to make and use. Detailed precautions and instructions are given in each paragraph where they apply. General safety precautions follow:

Preventing a Fire Hazard

1. Fire prevention is much more important than fire fighting. Prevent fires from starting.
2. Keep flammable liquids away from open flames.
3. Good housekeeping is the fire prevention. Keep work areas neat and orderly. Clean away all equipment and material not needed at the moment. Clean up spills as soon as possible.
4. Store incendiaries in closed containers away from heat. Do not store material any longer than necessary.
5. In the event of fire, remove the incendiaries from the danger area if this can be done quickly and safely. Use large quantities of water to fight fires.
6. Horse play is dangerous and absolutely intolerable.

Avoiding Chemical Hazards

1. Wear rubber gloves, apron, and glasses when handling concentrated chemicals if at all possible.
2. Avoid inhaling fumes. Perform reactions in a well ventilated area or out of doors because the boiling is often violent and large amounts of fumes are given off that are poisonous if breathed too much.
3. Avoid acid contact with the skin. If chemicals are spilled on a person, wash immediately in running water for several minutes. If they splash in the eyes, wash the open eye in running water for at least 15 minutes.
4. Clean up any acid that is spilled on floor or bench by flushing with large amounts of water. Acid spilled

on wood can cause a fire.

5. Always pour concentrated acids into water. Never pour water into concentrated acids because a violent reaction will occur.

CHAPTER 2
INITIATORS

0101. FUSE CORD

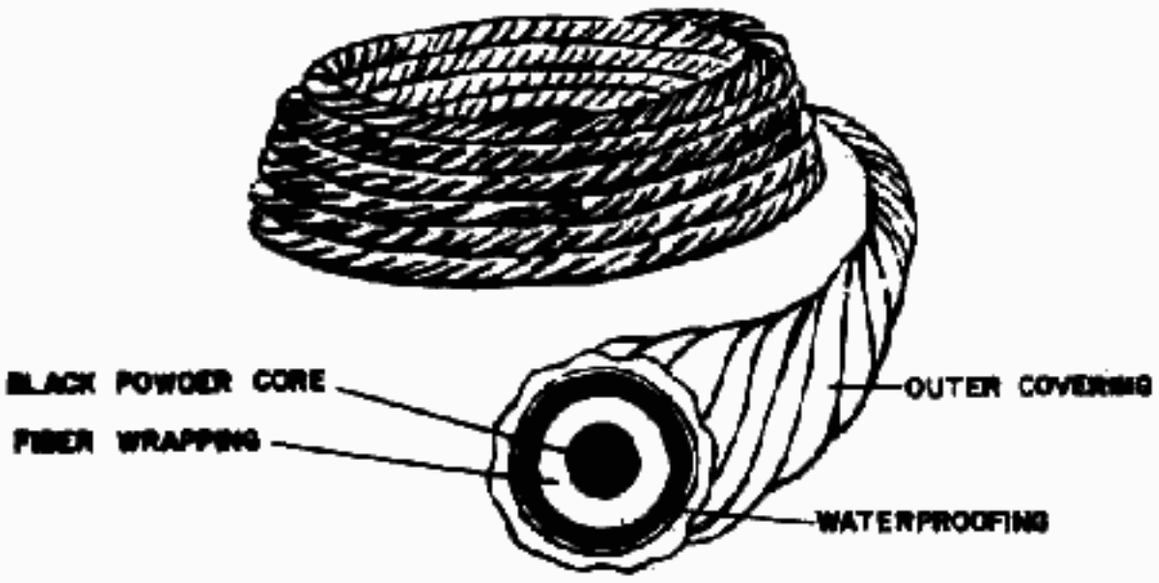
a. Description.

(1) This item consists of a continuous train of explosive or fastburning material enclosed in a flexible waterproof cord or cable. It is used for setting off an explosive or a combustible mixture of powders by action of the fuse flame on the material to be ignited. Fuse cord can be initiated by a match flame, using a specific procedure, or with a standard U.S. Army fuse lighter. Fuse cord burns at a uniform rate allowing the user to be away from the immediate scene when the incendiary actually functions.

(2) Fuse cord does not directly ignite any incendiaries listed in chapter 4 but is a primary initiator for all igniters listed in chapter 3 except: Potassium Permanganate—Glycer in (0206), Powdered Aluminum—Sulfur Pellets (0207), White Phosphorus (0209), and Sub-igniter For Thermite (0211).

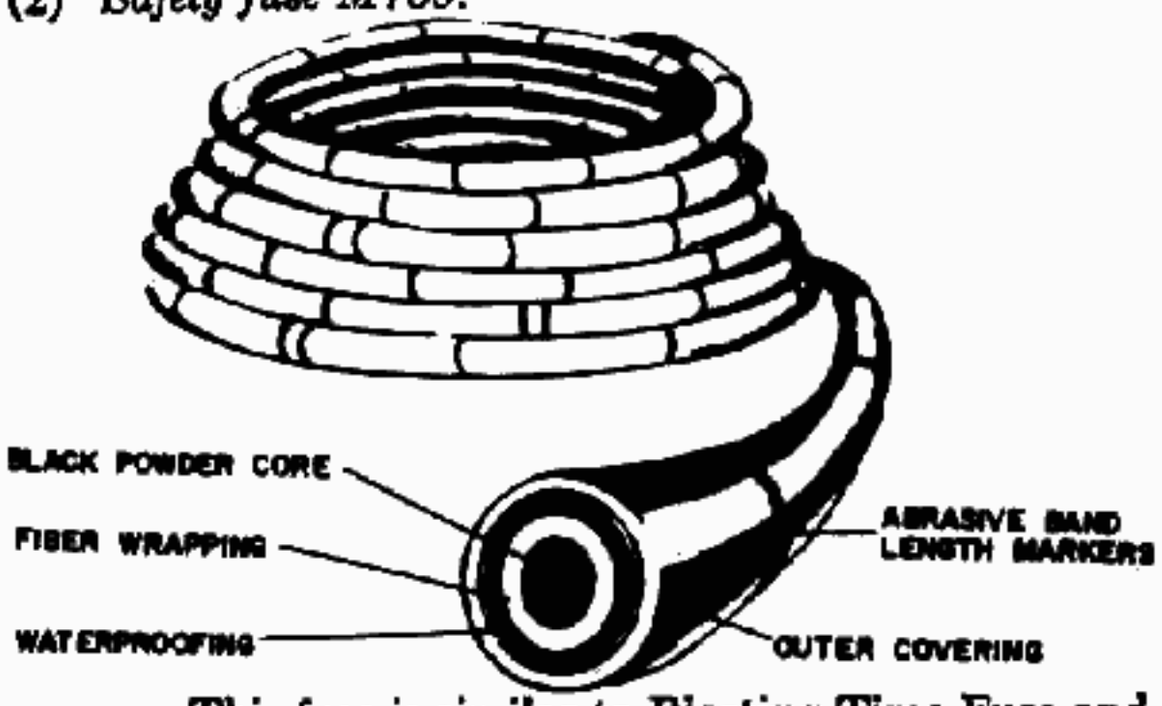
b. Material and Equipment. Two Standard U.S. Army fuse cords are available:

(1) *Blasting time fuse.*



This consists of black powder tightly wrapped with several layers of fabric and waterproofing materials. It might be any color, orange being the most common. The diameter of this fuse cord is 0.2 inch (a little larger than 1/5 inch). This fuse burns inside the wrapping at a rate of approximately 40 seconds per foot. It must be tested before use to verify the burning rate.

(2) *Safety fuse M700.*



This fuse is similar to Blasting Time Fuse and may be used interchangeably with it. The fuse is a dark green cord 0.2 inch in diameter with a plastic cover, either smooth or with single painted abrasive bands around the outside at 1 foot or 18 inch intervals and double painted abrasive bands at 5 foot or 90 inch intervals depending on the time of manufacture. These bands are provided to make measuring easy. They are abrasive so that they can be felt in the dark. The fuse burns inside the wrapping at a rate of approximately 40 seconds per foot. It must be tested before use to verify the burning rate.

Note. A commercial item can be substituted for either of the above U.S. Army issue items. The commercial fuse is 0.1 inch (about 1/8 inch) in diameter and is coated only with waterproofing lacquer. This fuse can be easily ignited by holding the free end in a match flame because the outside covering if flammable.

c. Preparation. None.

d. Application.

(1) *General.*

(a) Cut and discard a 6-inch length from the free end of the fuse roll. Do this to be sure that there is no chance of misfire from a damp powder train because of absorption of moisture from the open air. Then cut off a measured length of fuze to check the burning rate. Check the burning rate before actual use.

(b) Cut the fuse long enough to allow a reasonable time delay in initiation of the incendiary system. The cut should be made squarely across the fuse.

(c) Prepare the fuse for ignition by splitting the fuse at one end to a depth of about one inch. Place the head of an unlighted match in the powder train.

(*d*) Insert the other end of the fuse into a quantity of an igniter mixture so that the fuse end terminates near the center of the mixture. Be sure the fuse cord is anchored in the igniter mixture and cannot pull away. In the case of a solid igniter material such as Fire Fudge (0202), the fuse is split to about one-half inch at the end opposite the end containing the match in the powder train. This split fuse end is wedged over a sharp edge of the solid igniter material. Be sure the black powder in the fuse firmly contacts the solid igniter. If necessary, the fuse cord can be held firmly to the solid igniter with

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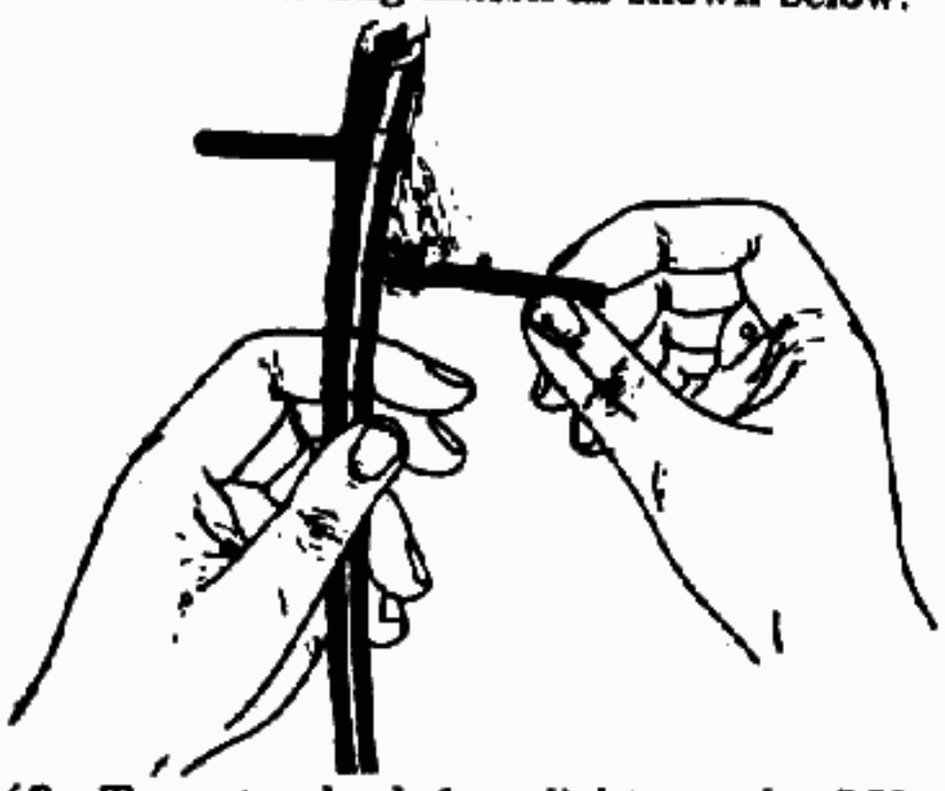
light tape such as transparent adhesive tape.

(*e*) The fuse is initiated by lighting the match head inserted in the split end of the fuse with a burning match as shown below.



(*f*) Two standard fuse lighters, the M2 and M60, are available in demolition kits for positive lighting of Blasting Time Fuse and Safety Fuse M700 under all weather conditions—even under water if it is properly waterproofed. The devices are manually operated. A pull on the striker retaining pin causes the striker to hit the percussion primer, thus igniting the fuse. *These devices are not recommended where silence is required because a report is heard when the primer is fired.*

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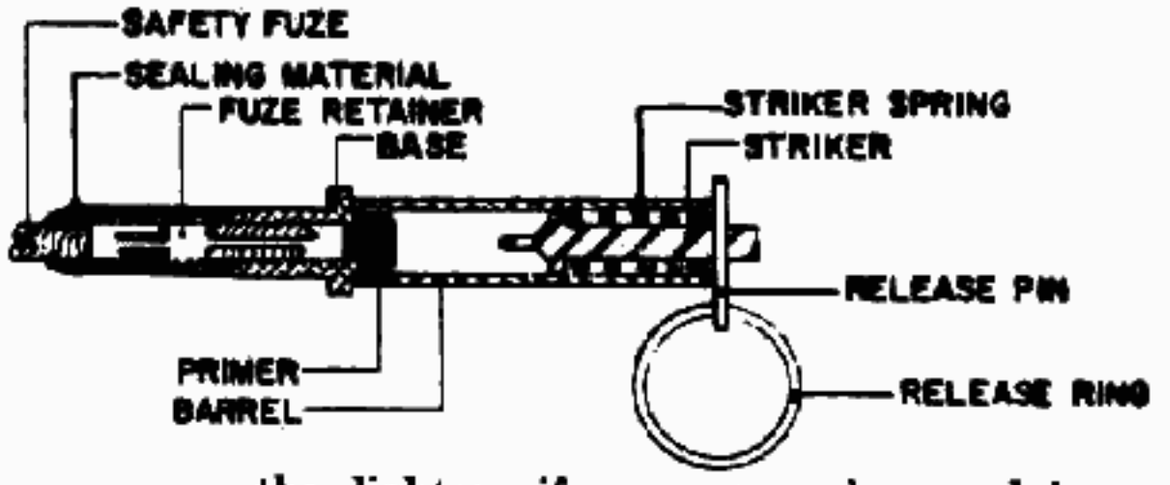
(2) *M2 fuse lighter.*

The attachment and operation of the M2 Fuse Lighter are as follows:

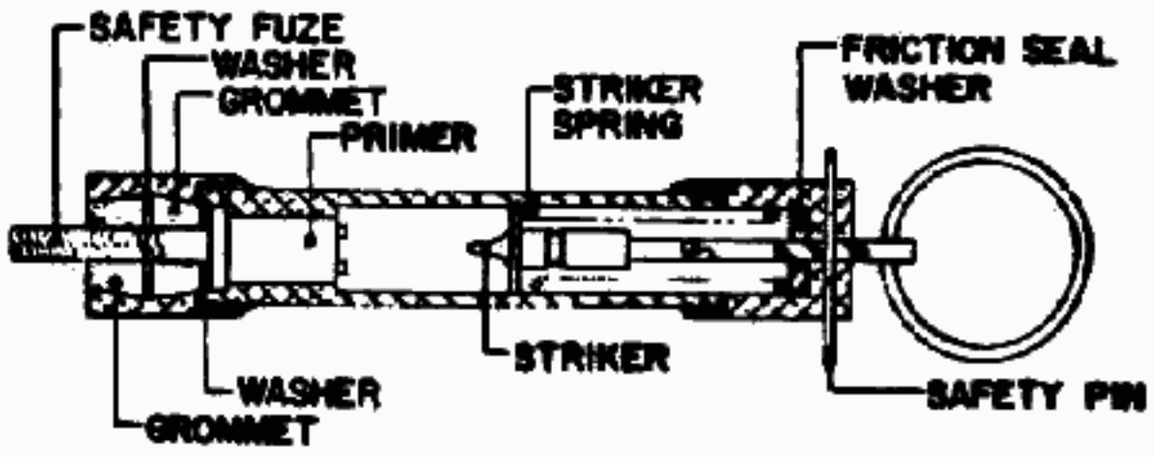
(*a*) Slide the pronged fuse retainer over the end of the fuse and firmly seat it.

(*b*) Waterproof the joint between the fuse and the lighter, if necessary, by applying a sealing compound (putty or mastic).



(*c*) In firing, hold the barrel in one hand and pull on the release pin with the other hand.

(3) *M60 fuse lighter.*



The attachment and operation of the M60 Fuse Lighter are as follows:

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(*a*) Unscrew the fuse holder cap two or three turns.

(*b*) Press the shipping plug into the lighter to release the split grommet, and rotate the plug as it is removed.

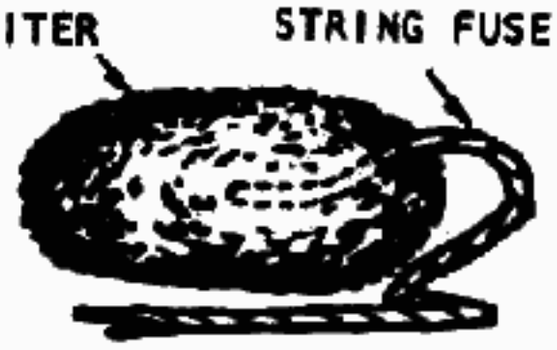
(*c*) Insert end of fuse in place of the plug until it rests against the primer.

(*d*) Tighten the fuse holder cap sufficiently to hold the fuse tightly in place and thus waterproof the joint.

(*e*) To fire, remove the safety pin, hold the barrel in one hand, and pull on the pull ring with the other hand.

0102. IMPROVISED STRING FUSE

a. Description.



(1) This item consists of string, twine, or shoelaces that have been treated with either a mixture of potassium nitrate and granulated sugar or potassium chlorate and granulated

sugar.

(2) Improvised string fuse does not directly ignite any incendiaries listed in chapter 4 but is a primary initiator for all igniters listed in chapter 3 except: Potassium Permanganate —Glycerin (0206), Powdered Aluminum—

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Sulfur Pellets (0207), White Phosphorus (0209), and Subigniter For Thermite (0211).

(3) Depending upon the length of the fuse, the user can be away from the immediate scene when an incendiary system is initiated.

b. Material and Equipment.

String, twine or shoelaces made of cotton or linen.
Potassium nitrate or potassium chlorate.
Granulated sugar.
Small cooking pot.
Spoon.
Heat source such as stove or hot plate.
Soap.

c. Preparation.

(1) Wash string or shoelaces in hot soapy water; rinse in fresh water.

(2) Dissolve one part potassium nitrate or potassium chlorate and one part granulated sugar in two parts hot water.

(3) Soak string or shoelaces in the hot solution for at least five minutes.

(4) Remove the string from hot solution and twist or braid three strands of string together.

(5) Hang the fuse up to dry.

(6) Check actual burning rate of the fuse by measuring the time it takes for a known length to burn.

d. Application.

(1) This fuse does not have a waterproof coating and it must be tested by burning a measured length before actual use.

(2) Cut the fuse long enough to allow a reasonable time delay in initiation of the incendiary system.

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(3) Insert one end of the fuse in a quantity of an igniter mixture so that the fuse end terminates near the center of the mixture. Be sure the fuse cord is anchored in the igniter mixture and cannot pull away. In the case of a solid igniter material such as Fire Fudge (0202), the improvised string fuse is securely wrapped around a piece of solid igniter material.

(4) The fuse is initiated by lighting the free end of the fuse with a match.

(5) This fuse does not burn when it is wet. Its use is not recommended where there is the possibility of the fuse getting wet.

0103. CONCENTRATED SULFURIC ACID (OIL OF VITRIOL)

a. Description.

(1) This material is a heavy, corrosive, oily, and colorless liquid. Storage is recommended in a glass container with a glass lid or stopper. Commercially available sulfuric acid is approximately 93 percent concentration with a specific gravity of 1.835. This is commonly referred to as concentrated sulfuric acid.

(2) Concentrated sulfuric acid chars wood, cotton, and vegetable fibers, usually without causing fire. The addition of water to concentrated sulfuric acid develops much heat which may be sufficient to cause a fire or an explosion. This depends upon the quantity of acid, quantity of water, and rate of addition of water.

Caution: **Always add concentrated sulfuric acid to water. Never add water to a concentrated acid.**

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(3) Certain igniter materials can be reliably brought to flaming by the addition of concentrated sulfuric acid. This is brought about by the chemical reaction between the sulfuric acid and the igniter materials. The following igniters are initiated by concentrated sulfuric acid: Sugar-Chlorate (0201), Fire Fudge (0202), Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), Match Head (0205), and Silver Nitrate—Magnesium Powder (0208).

(4) The most important use for concentrated sulfuric acid as an initiator is in conjunction with delay mechanisms. The acid is held away from the igniter for a period of time by making use of the corrosive action of the acid to work its way through a barrier. If the delay mechanism is placed in a cold environment, the concentrated acid will remain fluid at extremely low temperatures. The following delay mechanisms are recommended for use with concentrated sulfuric acid: Gelatin Capsule (0402), Rubber Diaphragm (0403), Paper Diaphragm (0404), Tipping Delay—Filled tube (0408), Tipping Delay—Balancing Stick (0410), and Stretched Rubber Band (0411).

b. Material and Equipment. Concentrated sulfuric acid.

c. Preparation. None—If only battery-grade sulfuric acid is available (specific gravity 1.200), it must be concentrated before use to a specific gravity of 1.835. This is done by heating it in an enameled, heat-resistant glass or porcelain pot until dense, white

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fumes appear. Heat only in a well ventilated area. When dense, white fumes start to appear, remove the heat and allow acid to cool. Store the concentrated acid in a glass container.

d. Application.

(1) *General.* Commercial sulfuric acid is available in 13 gallon carboys. Smaller quantities of this acid are available in chemical laboratory reagent storage containers. It is recommended that a small quantity of acid, about one pint, be secured and stored in a glass container until it is used.

(2) *Use with delay mechanisms.*

(*a*) Construction of specific delay mechanisms is described in chapter 5. Within the delay mechanism, there is a container filled with acid. The acid corrodes this container, is absorbed by the container material or is spilled from the container until it comes in contact with the igniter mixture.

(*b*) Carefully fill the container in the delay mechanism with concentrated sulfuric acid. This can be accomplished easily with a small glass funnel. A medicine dropper is used when the delay mechanism container is small.

Caution: **Concentrated sulfuric acid must be handled carefully because it is very corrosive. If it is splashed on clothing, skin or eyes, the affected area must be immediately flushed with water. This may not be always practical. It is recommended that eye protection be worn by the user when pouring concentrated sulfuric acid. Many types are**

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available for this purpose. Rubber gloves can be worn to protect the hands. A small bottle of water can be carried to flush small areas of skin or clothing which may be contaminated with the acid.

(3) *Manual application.*

(*a*) Manual application of concentrated sulfuric acid for direct initiation of an igniter is not recommended when fuse cord is available. It is possible to employ this acid for direct initiation by quickly adding three or four drops to the igniter material. This can be accomplished with a medicine dropper. Keep hands and clothing clear of the igniter; ignition may take place almost instantly with addition of acid.

Caution: **Do not allow material such as sugar, wood, cotton or woolen fibers to fall into the *boiling acid.* A violent reaction could occur with splattering of acid.**

(*b*) Since sulfuric acid has a unique freezing point related to acid concentration, the information shown below is useful when this acid is used with delay mechanisms in low temperature surroundings. Be sure of acid concentration by checking with a hydrometer.

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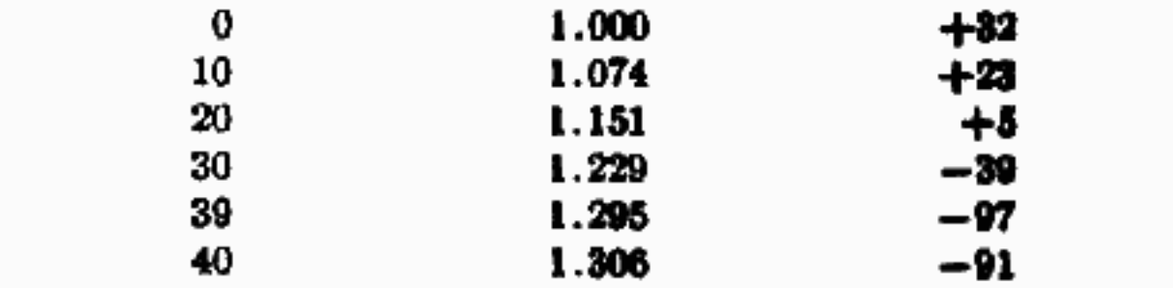

Sulfuric acid concentration (%)	*Specific gravity*	*Freezing point (° F.)*
0	1.000	+32
10	1.074	+23
20	1.151	+5
30	1.229	−39
39	1.295	−97
40	1.306	−91
50	1.408	−31
60	1.510	−22
70	1.611	−40
75	1.686	−7
77	1.706	+12
80	1.726	+27
81	1.747	+39
89	1.818	+24
90	1.824	+13
92	1.830	−1
93	1.835	−29

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0104. WATER

a. Description.

(1) Water causes spontaneous initiation of certain igniter mixtures. This is caused by a chemical reaction of the igniter materials in the presence

of water. The following igniters are initiated by water: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), and Silver Nitrate—Magnesium Powder (0208).

(2) The most important use for water as an initiator is in conjunction with delay mechanisms. Since only a few igniter mixtures are initiated by water and *it cannot be used at freezing temperatures,* its use is limited. When tactics so dictate, water can be reliably used with the following delay mechanisms: Gelatin Capsule (0402), Overflow (0407), Tipping Delay—Filled Tube (0408), Balancing Stick (0410), and Stretched Rubber Band (0411).

Note. Sulfuric acid of any concentration can be substituted for water in the initiation of water activated igniters. Water *cannot* be substituted for concentrated sulfuric acid.

b. Material and Equipment. Water.

c. Preparation. None.

d. Application.

(1) *Use with delay mechanisms.* Construction of specific delay mechanisms is presented in chapter 5. Within the delay mechanism, there is a container filled with water. The water dissolves the container or is spilled from the container and comes in contact with igniter mixture, initiating the fire train.

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(2) *Manual application.* Fuse cord, when available, is recommended in preference to water as an initiator. Water is used for direct ignition of a specific igniter by adding drops as with a medicine dropper. Keep hands and clothing clear of the igniter; ignition may take place almost instantaneously with addition of water.

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CHAPTER 3

IGNITERS

0201. SUGAR-CHLORATE

a. Description.

(1) This item consists of a mixture of granulated sugar and potassium chlorate or sodium chlorate. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101), Improvised String Fuse (0102), or Concentrated Sulfuric Acid (0103).

(3) This simple sugar-chlorate mixture closely resembles granulated sugar and should not ordinarily arouse suspicion. It is an excellent igniter.

***Caution:* This mixture is poisonous and must not be eaten.**

b. Material and Equipment.

Granulated sugar (do *not* use powdered or confectioners sugar.)
Potassium chlorate or sodium chlorate (no coarser than granulated sugar).
Spoon (preferably nonmetallic).
Container with tight-fitting lid.
Rolling pin or round stick.

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c. Preparation.

(1) Using a clean, dry spoon, place granulated sugar in the container to one-quarter container volume. Wipe the spoon with a clean cloth.

(2) If the potassium or sodium chlorate is lumpy, remove all lumps by crushing with a rolling pin. Using the spoon, add an equal quantity of chlorate to the container.

***Caution:* If this mixture is carelessly handled with excessive bumping and scraping, it could be a fire hazard to the user. As a precaution, remove any mixture adhering to the lip or edge of the jar before tightening the lid.**

(3) Tighten the lid of the jar, turn the jar on its side and slowly roll until the two powders are completely mixed. The mixture is now ready for use. It may be stored for months in a tightly sealed container.

d. Application.

(1) Carefully pour or spoon the mixture, in a single pile, on the incendiary. Prepare the mixture for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the igniter mixture. Concentrated Sulfuric Acid (0103) can be used as an initiator, but is generally less convenient. Ignition takes place almost immediately on contact with the acid. Acid is recommended for use with specific delay mechanisms found in chapter 5.

(2) If only battery-grade sulfuric acid is available, it must be concentrated before use to a

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specific gravity of 1.835 by heating it in an enameled, heat-resistant glass or porcelain pot

until dense, white fumes start to appear. See paragraph 0103 for details.

(3) When used to ignite flammable liquids, wrap a quantity of the mixture in a nonabsorbent material and suspend it inside the container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(4) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0202. FIRE FUDGE

a. Description.

(1) This item consists of a mixture of sugar and potassium chlorate in a hot water solution which solidifies when cooled to room temperature. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material, such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101), Improvised String Fuse (0102), or Concentrated Sulfuric Acid (0103).

(3) Fire fudge resembles a white sugar fudge having a smooth, hard surface. The advantage of this igniter material over Sugar-Chlorate (0201), is its moldability. The

procedure for preparation must be followed closely to obtain a smooth, uniform material with a hard surface.

***Caution:* This material is poisonous and must not be eaten.**

b. Material and Equipment.

Granulated sugar (do *not* use powdered or confectioners sugar).

Potassium chlorate (no coarser than granulated sugar).

Metallic, glass or enameled pan.

Measuring container (size of this container determines quantity of finished product).

Spoon (preferably nonmetallic).

Thermometer (to read in the range 200° F. to 250° F.)

Heat source.

c. Preparation.

(1) Clean the pan by boiling some clean water in it for about five minutes. Discard the water, pour one measureful of clean water into the pan and warm it. Dry the measuring container and add one measureful of sugar. Stir the liquid until the sugar dissolves.

(2) Boil the solution until a fairly thick syrup is obtained.

(3) Remove the pan from the source of heat to a distance of at least six feet and shut off heat. Rapidly add two measurefuls of potassium chlorate. Stir gently for a minute to mix the syrup and powder, then pour or spoon the mixture into appropriate molds. If the mold is paper, it can usually be peeled off when the fire fudge cools and hardens. Pieces of card-

board or paper adhering to the igniter will not impair its use. Pyrex glass or ceramic molds can be used when a clear, smooth surface is desired. It is recommended that section thickness of molded fire fudge be at least one-half inch. If desired, molded fire fudge can be safely broken with the fingers.

(4) This material is moderately hard immediately after cooling. It will become harder after 24 hours. When kept in a tightly sealed container, it will retain its effectiveness for months.

***Caution:* If this igniter material is carelessly handled with excessive bumping or scraping, it could be a fire hazard to the user.**

d. Application.

(1) Place a piece of fire fudge on top of the incendiary. Minimum size should be about one inch square and one-half inch thick. Prepare the fire fudge for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. Concentrated Sulfuric Acid (0103) can be used as an initiator but is generally less convenient. Acid is recommended for use with specific delay mechanisms found in chapter 5.

(2) If only battery-grade sulfuric acid is available, it must be concentrated before use to a specific gravity of 1.835 by heating it in an enameled, heat resistant glass or porcelain pot until dense, white fumes start to appear. See paragraph 0103 for details.

(3) When used to ignite flammable liquids, wrap a quantity of the igniter mixture in a nonabsorbent material and suspend it inside the

container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(4) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0203. SUGAR—SODIUM PEROXIDE

a. Description.

(1) This item consists of a mixture of sodium peroxide and granulated sugar. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material such as rags, dry paper dry hay, or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101), Improvised String Fuse (0102), Concentrated Sulfuric Acid (0103), or Water (0104).

***Caution:* This mixture is unstable and can ignite at high humidity or when wet slightly by drops of water, perspiration, etc.**

b. Material and Equipment.

Granulated sugar (do *not* use powdered or confectioners sugar).

Sodium peroxide (no coarser than granulated sugar).

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Spoon.

Container with tight fitting lid for mixing and storage.

c. Preparation.

(1) Using a clean, dry spoon, place granulated sugar in the container to one-quarter container volume.

(2) Wipe the spoon with a clean, dry cloth, and add an equal amount of sodium peroxide to the dry mixing container. Tighten the lid on the sodium peroxide container, and remove it at least six feet from the working area.

(3) Tighten the lid on the mixing container. Turn the container on its side and slowly roll until the two powders are completely mixed. The mixture is now ready for use.

(4) A good practice is to keep the granulated sugar and sodium peroxide in separate air-tight containers and mix just before use.

***Caution:* Do not store this mixture longer than three days because decomposition may occur and cause spontaneous combustion. Be sure that the storage container is air-tight.**

d. Application.

(1) Carefully pour or spoon the mixture, in a single pile, on the incendiary. Prepare the mixture for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the igniter mixture. Concentrated Sulfuric Acid (0103) and Water (0104) can be used as initiators, but are generally less convenient. Ignition takes place almost immediately on contact with the

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acid or water. These liquid initiators are convenient for use with specific delay mechanisms found in chapter 5.

(2) When used to ignite flammable liquids, wrap a quantity of the mixture in a non-absorbent material and suspend it inside the container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(3) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top of an open container of flammable liquid before lighting the fuse.

0204. ALUMINUM POWDER—SODIUM PEROXIDE

a. Description.

(1) This item consists of a mixture of sodium peroxide and powdered aluminum. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material, such as rags, dry paper, dry hay or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101), Improvised String Fuse (0102), Concentrated Sulfuric Acid (0103), or water (0104).

***Caution:* This mixture is unstable and can ignite at high humidity or when wet slightly by drops of water, perspiration, etc.**

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b. Material and Equipment.

Powdered aluminum (no coarser than granulated sugar).

Sodium peroxide (no coarser than granulated

sugar).
Spoon.
Container with tight fitting lid for mixing and storage.

c. *Preparation.*

(1) Using a clean, dry spoon, place powdered aluminum in the container to one-quarter container volume.

(2) Wipe the spoon with a clean, dry cloth, and add an equal amount of sodium peroxide to the dry mixing container. Tighten the lid on the sodium peroxide container, and remove it at least six feet from the working area.

(3) Tighten the lid of the mixing container. Turn the container on its side and slowly roll until the two powders are completely mixed. The mixture is now ready to use.

(4) A good practice is to keep the powdered aluminum and sodium peroxide in separate containers and mix just before use.

Caution: **Do not store this mixture longer than three days because decomposition may occur and cause spontaneous combustion. Be sure that the storage container is air-tight.**

d. *Application.*

(1) Carefully pour or spoon the mixture, in a single pile, on the incendiary. Prepare the mixture for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate

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near the center of the igniter mixture. Concentrated Sulfuric Acid (0103) and Water (0104) can be used as initiators, but are generally less convenient. Ignition takes place almost immediately on contact with the acid or water. These liquid initiators are convenient for use with specific delay mechanisms found in (chapter 5.)

(2) When used to ignite flammable liquids, wrap a quantity of the mixture in a nonabsorbent material and suspend it inside the container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(3) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0205. MATCH HEAD

a. *Description.*

(1) This item consists of a quantity of match heads, prepared by breaking the heads off their match sticks and grouping the match heads together to form the desired quantity of igniter. Any kind of friction match will do. It can be used to ignite the following incendiaries listed in chapter 4: Napalm (0301), Gelled Gasoline (exotic thickeners) (0302), Gelled Gasoline (improvised thickeners) (0303), Paraffin-Sawdust (0304), and Flammable Liquids (0308). It may be used directly

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as an incendiary on readily flammable material such as rags, dry paper, dry hay or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by a match flame, Fuse Cord (0101), Improvised String Fuse (0102), or Concentrated Sulfuric Acid (0103).

b. *Material and Equipment.*

Razor blade or knife.
Container with tight-fitting lid.
Matches, friction.

c. *Preparation.*

(1) Using a knife or razor blade, cut off the match heads.

(2) Prepare the desired quantity of igniter and store it in an airtight container until ready for use.

d. *Application.*

(1) Pour or spoon the match heads, in a single pile, on the incendiary. Prepare the match heads for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the match head pile. Concentrated Sulfuric Acid (0103) or a match flame can also be used as an initiator. Ignition takes place almost immediately on contact with the acid or the match flame. Acid is recommended for use with specific delay mechanisms found in chapter 5.

(2) If only battery-grade sulfuric acid is available, it must be concentrated before use to a specific gravity of 1.835 by heating it in an enameled, heat-resistant glass or porcelain

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pot until dense, white fumes start to appear. See paragraph 0103 for details.

(3) When used to ignite flammable liquids, wrap a quantity of the match heads in a nonabsorbent material and suspend it inside the container near the open top. The container

must remain open for easy ignition and combustion of the flammable liquid.

(4) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0206. POTASSIUM PERMANGANATE—GLYCERIN

a. Description.

(1) This item consists of a small pile of potassium permanganate crystals which are ignited by the chemical action of glycerin on the crystals. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material, such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) Ignition is accomplished by causing a few drops of glycerin to contact the potassium permanganate crystals. A hotter flame is produced when powdered magnesium or powdered aluminum is mixed with the the potassium permanganate crystals.

(3) Ignition time, after addition of the glycerin, increases as temperature decreases. This igniter is not reliable below 50° F.

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b. Material and Equipment.

Potassium permanganate crystals (no coarser than granulated sugar).

Glycerin.

One small container with tight-fitting lid for the glycerin.

One larger container with tight-fitting lid for the potassium permanganate crystals.

Powdered magnesium or powdered aluminum (no coarser than granulated sugar).

c. Preparation.

(1) Put some glycerin in the small container and cap tightly.

(2) Fill the larger container with potassium permanganate crystals and cap tightly.

(3) If powdered magnesium or powdered aluminum is available, mix 85 parts potassium permanganate crystals and 15 parts powdered magnesium or powdered aluminum and store this mixture in the large bottle.

(4) Keep these containers tightly sealed and the material in the containers will remain effective for a long period of time.

d. Application. Pour out a quantity of the potassium permanganate crystals (with or without powdered aluminum or powdered magnesium), in a single pile on the incendiary. Manual ignition is accomplished by causing a few drops of glycerin from a medicine dropper to come in contact with the potassium permanganate crystals. Keep hands and clothing clear of the igniter; ignition may take place almost instantly with addition of the glycerin. This igniter is convenient for use with specific delay mechanisms found in chapter 5.

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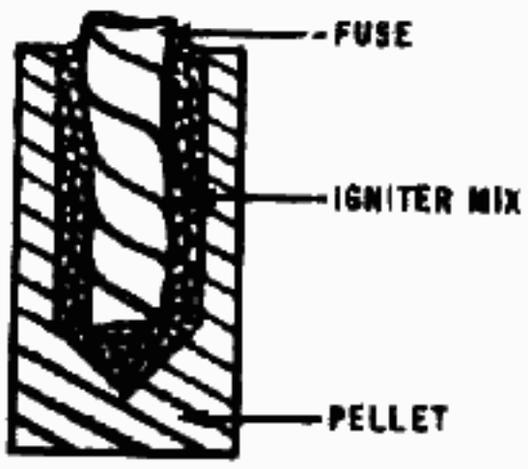
0207. POWDERED ALUMINUM—SULFUR PELLETS

a. Description.



(1) This igniter consists of finely powdered aluminum, sulfur and starch which have been thoroughly mixed and shaped into hardened cylindrical pellets. It can be used to ignite all the incendiaries listed in chapter 4. It is an excellent igniter for Thermite (0307). It may be used directly as an incendiary on readily flammable material such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101) or Improvised String Fuse (0102). A hole is made in one pellet to receive a fuse and a small quantity of another more easily started igniter mixture. A number of unmodified pellets are attached to the first pellet to increase the quantity of heat after combustion occurs.

b. Material and Equipment.

Finely powdered aluminum (no coarser than cake flour).

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Finely powdered sulfur (no coarser than cake flour).

Finely powdered starch (no coarser than cake flour).

Water.

Cylindrical tube about 4 inches long and ¾ inch inside diameter made of metal, wood, glass or plastic.

Rod which fits into the above tube.

Rod about ⅜ inch in diameter (should be about

one-half the inside diameter of the 4-inch long tube).
Mixing bowl.
Tablespoon.
Teaspoon.
Stove or hot plate.
Knife.
Measuring container.

c. Preparation.

(1) Place six tablespoons of aluminum powder in a mixing bowl then add 15 tablespoons of powdered sulfur.
(2) Mix the two powders gently with the spoon for a few minutes until no unmixed particles of sulfur are visible.
(3) In a separate pot add two teaspoons of laundry starch to about 6 ounces of water and boil gently for a few minutes. Stir until the starch is dissolved and allow the solution to cool to room temperature.
(4) When cool, take about one-half of the starch solution and add it to the mixture of aluminum and sulfur powder.

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(5) Mix with a spoon until the whole mass is a smooth, evenly mixed, putty-like paste.
(6) Fill the cylindrical tube with this paste, place one end of this tube on a hard surface and tamp the paste with the ⅜ inch diameter rod to squeeze out the air bubbles and consolidate the paste.
(7) Push the paste out of the tube with the larger rod, which just fits the tube, so that it forms a cylinder, then cut the damp cylinder into 1½ inch lengths using the knife.
(8) Dry these pieces at 90° F. for at least 24 hours before using. The drying time can be reduced by using a drying oven at a maximum temperature of 150° F.
(9) Form a hole at least ½ inch in diameter approximately half-way into one end of an igniter pellet.
(10) Put one of the following igniters into the cavity to roughly one-half its depth:
Sugar-Chlorate (0201)
Sugar—Sodium Peroxide (0203)
Aluminum Powder—Sodium Peroxide (0204)
Silver Nitrate—Magnesium Powder (0208)
(11) Insert a length of fuse into the hole so that it makes contact with the igniter mix. Fill the remainder of the hole with igniter mix and tamp down to hold the fuse firmly.
(12) Tape the fuse cord in place to prevent it from working loose and falling out.
(13) Tape two or more pellets without holes to the one with the fuse.
(14) Store all the pellets in a dry, closed container until required for use.

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d. Application.

(1) For ignition of thermite, a cluster of at least three pellets should be used. Bury the cluster of igniter pellets just below the surface of the thermite, with the fuse extending for ignition by a match flame. Large quantities of thermite may require a cluster of more than three pellets for satisfactory ignition.
(2) For use as an igniter of a solid incendiary, place a cluster of pellets on top of the incendiary.
(3) When used to ignite flammable liquids, wrap a cluster of igniter pellets in a nonabsorbent material and suspend it inside the container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.
(4) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0208. SILVER NITRATE—MAGNESIUM POWDER

a. Description.

(1) This item consists of a mixture of silver nitrate crystals and magnesium powder. It can be used to ignite all the incendiaries listed in chapter 4 except Thermite (0307). It may be used directly as an incendiary on readily flammable material such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

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(2) The igniter can be initiated by Fuse Cord (0101), Improvised String Fuse (0102), Concentrated Sulfuric Acid (0103), or Water (0104).

***Caution:* This mixture is unstable and may ignite at high humidity or when wet slightly by drops of water, perspiration, etc.**

b. Material and Equipment.

Silver nitrate crystals (no coarser than granulated sugar).
Magnesium powder or filings (no coarser than

granulated sugar).
Spoon.
Container with tight-fitting lid.

c. *Preparation.*

(1) Using a clean, dry spoon, place magnesium powder or filings into the dry mixing container to one-quarter container volume. If magnesium filings are used, they should be free of grease.

(2) Wipe the spoon with a clean, dry cloth, then add an equal quantity of silver nitrate crystals to the dry mixing container. Tighten the lid on the silver nitrate container, and remove it at least six feet from the working area.

(3) Tightly close the lid on the mixing container. Turn the container on its side and slowly roll until the two powders are completely mixed. The mixture is now ready for use.

(4) A good practice is to keep the silver nitrate crystals and the magnesium powder or filings in separate air-tight containers and mix just before use.

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Caution: **This mixture should be kept out of direct sunlight to avoid decomposition of the silver nitrate which could render this igniter mixture ineffective.**

d. *Application.*

(1) Carefully pour or spoon the mixture, in a single pile, on the incendiary. Prepare the mixture for ignition with either Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the igniter mixture. Concentrated Sulfuric Acid (0103) and Water (0104) can be used as initiators but are generally less convenient. Ignition takes place almost immediately on contact with the acid or water. These liquid initiators are convenient for use with specific delay mechanisms found in chapter 5.

(2) When used to ignite flammable liquids, wrap a quantity of the mixture in a nonabsorbent material and suspend it inside the container near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(3) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0209. WHITE PHOSPHORUS

a. *Description.*

(1) This item consists of white phosphorus dissolved in carbon disulfide. It can be used to

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ignite the following incendiaries listed in chapter 4: Napalm (0301), Gelled Gasoline (exotic thickeners) (0302), Gelled Gasoline (improvised thickeners) (0303), and Paraffin-Sawdust (0304). It may be used directly as an incendiary on readily flammable material such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) Ignition is achieved when the volatile solvent, carbon disulfide, evaporates and the white phosphorus comes in contact with air.

Caution: **Never touch white phosphorus directly or allow any of its solutions to touch the skin. Painful burns which heal very slowly may result. White phosphorus sticks must *always* be stored completely under water. If any of the phosphorus solution is accidently spilled on the skin, immediately flush the affected area with water; then decontaminate the affected area by dabbing with copper sulfate solution.**

b. *Material and Equipment.*

White phosphorus sticks (sometimes called yellow phosphorus).
Carbon disulfide.
Copper sulfate solution.
Tweezers or tongs.
Two glass containers about 8-ounce capacity with lids or stoppers made of glass, earthenware, or metal. Do not use a rubber lid or stopper (carbon disulfide will attack rubber).

c. *Preparation.*

(1) Prepare some copper sulfate solution by adding one spoonful of copper sulfate crystals

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to one of the glass containers. Fill the container with water, place the stopper in the open mouth of the bottle and shake until the crystals dissolve.

(2) Pour carbon disulfide into the other glass container to one-quarter container volume.

Caution: **Carbon disulfide fumes are poisonous. Always cap an open container of carbon disulfide as soon as possible. Work in a well ventilated area.**

(3) With a pair of tweezers remove some sticks of white phosphorus from their storage container.

Totally submerge them immediately in the carbon disulfide to bring the level up to one-half full. Be sure that all the phosphorus left in the original container is completely submerged in water before putting the container away. Wash the tweezers immediately in the copper sulfate solution.

(4) Securely stopper the bottle containing the white phosphorus and carbon disulfide and allow to stand until the white phosphorus dissolves. This usually takes about eight hours. The time required to dissolve white phosphorus can be reduced by shaking the bottle. Be sure that the bottle top does not come off.

(5) Do not store in direct sunlight because the solution will become ineffective. This solution should never be stored more than three days.

Note. If carbon disulfide is not available, benzene (benzol) may be used to dissolve the phosphorus. It requires considerable shaking and overnight soaking to get an appreciable amount of phosphorus dissolved

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in benzene. *Do not* attempt to use red phosphorus for preparing this igniter because it does not behave like white phosphorus.

d. Application.

(1) To ignite readily flammable material, pour the white phosphorus solution directly onto the material; it will ignite when the solvent evaporates, exposing the white phosphorus to the air. Once the solution is poured, the empty bottle should be discarded immediately because any solution remaining on the bottle will ignite when the solvent evaporates. Do not cover the soaked flammable material because the carbon disulfide must evaporate for ignition to occur.

(2) The incendiaries mentioned under *Description* above can be initiated by first impregnating crumpled paper or absorbent paper towels with the white phosphorus solution and placing the impregnated paper on the material to be ignited.

(3) Delay times of the phosphorus solution may be varied by the addition of gasoline or toluene (toluol). Add a small quantity of either solvent to the original white phosphorus solution and test the solution each time until the desired delay time is achieved. Delay times of 20 to 30 minutes may be obtained in this manner.

(4) Check the delay time under conditions expected at the target. Air currents hasten the evaporation of the solvent and decrease delay time. A high ambient temperature will also decrease delay time whereas a low ambient

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temperature will increase the delay time. This igniter is not reliable at or below freezing temperatures (32° F.)

(5) To make incendiary paper, soak strips of ordinary writing paper in the phosphorus-carbon disulfide for a few minutes. Remove the paper with a pair of tweezers or tongs and place in a vial filled with water. Be sure to wash off the tweezers immediately in copper sulfide solution. Cap the vial and store until ready to use. To use this incendiary paper, remove the strips of paper with a pair of tweezers, and place among the material to be ignited.

0210. MAGNESIUM POWDER—BARIUM PEROXIDE

a. Description.

(1) This item consists of a mixture of finely powdered magnesium and finely powdered barium peroxide. It can be used to ignite all the incendiaries listed in chapter 4 and is particularly suited for ignition of thermite. It may be used directly as an incendiary on readily flammable material such as rags, dry paper, dry hay, or in the combustible vapor above liquid fuels.

(2) The igniter can be initiated by Fuse Cord (0101) or Improvised String Fuse (0102).

b. Material and Equipment.

Magnesium powder (no coarser than table salt).
Barium peroxide (no coarser than table salt).
Spoon.
Container with tight-fitting lid.

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c. Preparation.

(1) Using a clean, dry spoon, place powdered magnesium into the dry mixing container to one-quarter container volume.

(2) Wipe the spoon with a clean, dry cloth, then add powdered barium peroxide to the dry mixing container to three-quarters container volume. Tighten the lid on the barium peroxide container, and remove it at least six feet from the working area.

(3) Tightly close the lid on the mixing container. Turn the container on its side and slowly roll until the two powders are completely mixed. The mixture is now ready for use.

(4) A good practice is to keep the powdered magnesium and powdered barium peroxide in separate containers and mix just before use.

d. Application.

(1) Carefully pour or spoon the mixture, in a single pile, onto the incendiary. Prepare the mixture for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the igniter mixture.

(2) In ignition of thermite, spread the igniter mixture to a depth of at least ¼ inch on the top surface of the thermite which is held in an assembly described under *Application* of Thermite incendiary (0307). The fuse cord will initiate the thermite igniter which will, in turn, ignite the thermite.

(3) When used to ignite flammable liquids, wrap a quantity of the mixture in a nonabsorbent material and suspend it inside the container

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near the open top. The container must remain open for easy ignition and combustion of the flammable liquid.

(4) To minimize the hazard of premature ignition of flammable liquid vapors, allow at least two feet of fuse length to extend from the top edge of an open container of flammable liquid before lighting the fuse.

0211. SUBIGNITER FOR THERMITE

a. Description.

(1) This item consists of a mixture of a metal powder and an oxidizing agent. Two metal powder alternates and four oxidizing agent alternates are specified. In the combustion process, the metal powder is oxidized, resulting in the liberation of a large quantity of heat.

(2) This subigniter is a substitute for Magnesium Powder—Barium Peroxide Igniter (0210), and should be used only if that Igniter is not available. The disadvantage of this subigniter is that it cannot be directly initiated by fuse cord. To use this subigniter for initiating thermite, it is necessary to use another igniter mixture to initiate the subigniter, preferably Sugar-Chlorate (0201). The fuse cord will initiate the sugar-chlorate, which will, in turn, ignite the subigniter and, thereby, initiate the thermite.

(3) This subigniter can be directly initiated by all the igniters listed in chapter 3 except White Phosphorus (0209).

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b. Material and Equipment.

Either aluminum or magnesium filings or powder (no coarser than granulated sugar).

Any one of the following oxidizing agents: sodium dichromate, potassium permanganate, potassium nitrate, or potassium dichromate (no coarser than granulated sugar).

Container with tight-fitting lid.

c. Preparation.

(1) Using a clean, dry spoon, place one of the metal powders or filings in the container to one-third container volume. If metal filings are used, they should be free of grease.

(2) Wipe the spoon with a clean, dry cloth and add an equal quantity of one of the above oxidizing agents.

(3) Tighten the lid on the mixing container, turn the container on its side and slowly roll until the two powders are completely mixed. The mixture is now ready to use and may be stored for months in this tightly sealed container.

d. Application.

(1) To use this subigniter, spread the material to a depth of at least ¼ inch on the top surface of the thermite which is held in an assembly described under *Application* of Thermite Incendiary (0307). Spread another igniter, preferably Sugar-Chlorate (0201) on top of this subigniter to about the same depth. Prepare the mixture for ignition with Fuse Cord (0101) or Improvised String Fuse (0102) in the normal manner. The fuse cord should terminate near the center of the igniter

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mixture. The fuse cord initiates the sugar-chlorate igniter which ignites the thermite subigniter which then ignites the thermite.

(2) For delay times longer than those conveniently obtained with fuse cord in ignition of thermite by this subigniter method, refer to chapter 5.

***Caution:* Never attempt to ignite thermite subigniter without at least a few seconds delay fuse. It burns extremely fast and hot, and the user could be seriously burned if he were too close when ignition occurred.**

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CHAPTER 4

INCENDIARY MATERIALS

0301. NAPALM

a. Description.

(1) This item consists of a liquid fuel which is gelled by the addition of soap powder or soap chips. It is easily prepared from readily available materials.

(2) This incendiary can be directly initiated by a match flame. However, if delay is required, the incendiary can be reliably initiated by a delay system consisting of any igniter listed in chapter 3 coupled with a delay mechanisms found in chapter 5.

(3) Napalm incendiary is easily ignited and long burning, and is suitable for setting fire to large wooden structures and other large combustible targets. It adheres to objects, even on vertical surfaces.

b. Material and Equipment.

Soap powder or chips (bar soap can be easily shaved or chipped). Detergents *cannot* be used.

Any of the following liquid hydrocarbon fuels: gasoline, fuel oil, diesel oil, kerosene, turpentine, benzol or benzene, toloul or toluene.

A double boiler made from any material with the upper pot having a capacity of at least two quarts.

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A spoon or stick for stirring.

A source of heat such as a stove or hot plate.

A knife or grater if only bar soap is available.

An air-tight container.

c. Preparation.

(1) Fill bottom of double boiler with water and heat until the water boils. Shut off source of heat.

(2) Place upper pot on top of bottom pot and remove both containers to a point several feet from the heat source.

(3) Pour soap chips or powder into the upper pot of the double boiler to one-quarter of pot volume.

(4) Pour any one of the liquid hydrocarbon fuels listed under *Material and Equipment* above into the upper pot containing the soap chips or powder until the pot is one-half full.

***Caution:* Keep these fuels away from open flames.**

(5) Stir the mixture with a stick or spoon until it thickens to a paste having the consistency of jam. Do this in a well ventilated room where the vapors will not concentrate and burn or explode from a flame or spark.

(6) If the mixture has not thickened enough after about 15 minutes of stirring, remove the upper pot and put it several feet from the heat source. Again bring the water in the lower pot to a boil. Shut off heat source, place upper pot in lower pot at a location several feet from the heat source and repeat stirring until the napalm reaches the recommended consistency.

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(7) When the proper consistency is obtained, store the finished napalm in a tightly sealed container until used. Napalm will keep for months when stored this way.

d. Application.

(1) To use napalm most effectively, it should be spread out over the surface of the material to be burned. This will start a large area burning at once. A match can be used to directly initiate this incendiary. A short time delay in ignition can be obtained by combining Fuse Cord (0101) or Improvised String Fuse (0102) and one of the igniter mixtures found in chapter 3. (For example, several spoonfuls of Sugar-Chlorate mixture (0201) are placed in a nonabsorbent wrapping material. Fuse cord is buried in the center of the igniter mixture and the fuse is taped to the wrapping material. This assembly is placed directly on the napalm. Delay times are determined by the length of fuse. Suitable delay mechanisms are given in chapter 5 for delay times longer than those practical with fuse cord.)

(2) Napalm made with the more volatile fuels should not ordinarily be used with a delay longer than one hour because the liquid fuel evaporates and this can reduce its effectiveness. In very hot weather, or if the napalm is exposed to the direct rays of the sun, it is recommended that napalm be made with fuel oil. In extremely cold weather, it is recommended that napalm be made with gasoline.

(3) The destructive effect of napalm is increased when charcoal is added. The charcoal will

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readily ignite and the persistent fire from the charcoal will outlast the burning napalm. It is recommended that at least one quart of napalm be used to ignite heavy wooden structures and large wooden sections. A minimum of one-half quart is recommended for wooden structures of small cross section.

0302. GELLED GASOLINE (EXOTIC THICKENERS)

a. Description.

(1) This item consists of gasoline which is gelled with small quantities of organic chemicals. The operation is carried out quickly, without heat, by addition of the chemicals while stirring.

(2) This incendiary can be directly initiated by a match flame. However, any igniter listed in chapter 3 can be used in conjunction with specific delay mechanisms found in chapter 5 for delayed ignition of this incendiary.

(3) Gelled gasoline incendiary is readily ignited, long burning, and is suitable for setting fire to large wooden structures and other large combustible targets. It adheres to objects, even on vertical surfaces.

b. Material and Equipment.

Gasoline.
Balance or scale.
Spoon or stick for stirring.
Large air-tight container.
Small jar.

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One of the following seven additive systems:

Components	Grams added per gal gas	Trade name	Manufacturer
SYSTEM 1			
A.. Lauryl amine..	55..	Alamine 4D Formonyte 616 Armeen.	General Mills Foremost Chemical Armour Chemical.
B.. Toluene diisocyanate.	27..	Hylene TM–65 Nacconate 65.	DuPont National Aniline.
SYSTEM 2			
A.. Coco amine....	55..	Alamine 21 Formonyte 601.	General Mills Foremost Chemical.
B.. Toluene diisocyanate.	27..	Hylene TM–65 Nacconate 65.	DuPont National Aniline.
SYSTEM 3			
A.. Lauryl amine..	57..	Alamine 4D Formonyte 616 Armeen.	General Mills Foremost Chemical Armour Chemical.
B.. Hexamethylene diisocyanate.	25..	Hexamethylene diisocyanate.	Borden Chemical
SYSTEM 4			
A.. Oleyl amine....	59..	Alamine II Formonyte 608.	General Mills Foremost Chemical.
B.. Hexamethylene diisocyanate.	23..	Hexamethylene diisocyanate.	Borden Chemical
SYSTEM 5			
A.. t-Octyl amine..	51..	t-Octyl.....	Rohm and Haas
B.. Toluene diisocyanate.	31..	Hylene TM–65 Nacconate 65.	DuPont National Aniline.

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Components	Grams added per gal gas	Trade name	Manufacturer
SYSTEM 6			
A.. Coco amine....	51..	Alamine 21 Formonyte 601.	General Mills Foremost Chemical.
B.. Naphthyl isocyanate.	31..	Naphthyl isocyanate.	Distillation Products Industry.
SYSTEM 7			
A.. Delta-aminobutylmethyldiethoxysilane.	51..	Delta silane....	Union Carbide
B.. Hexamethylene diisocyanate.	31..	Hexamethylene diisocyanate.	Borden Chemical

c. Preparation.

(1) Determine the amount of gasoline to be gelled and place this amount in the large container.

***Caution:* Keep this material away from open flames.**

(2) Weigh out the appropriate quantity of component A. This can be calculated by multiplying the number of gallons of gasoline by the figure given in the *Grams Added Per Gal. Gas.* column of systems. (For example, if System 1 is being used and five gallons of gasoline are being gelled, then (5×55) or 275 grams of Lauryl amine are required).

(3) Add component A to the gasoline and stir for a few minutes to dissolve.

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***Caution:* Both components A and B are corrosive to the skin. If any of these materials contact the skin, wash the area with detergent and water.**

(4) Clean the small container used to weight component A thoroughly or use another container for weighing component B. Weigh out the proper quantity of component B. Calculate the proper amount as mentioned above for component A.

(5) Stir the gasoline—component A mixture rapidly and add all of component B at once, not a little at a time. At the same time that component B enters the mixture, remove the stirring rod and allow a few minutes for the gelling to take place.

(6) Store the gelled gasoline in a tightly sealed container until ready to use. It will keep for months when stored in this manner.

d. Application.

(1) To use gelled gasoline most effectively, it should be spread out over the surface of the material to be burned. This will start a large area burning at once. A match can be used to directly initiate this incendiary. A short time delay in ignition can be obtained by combining Fuse Cord (0101), or Improvised String Fuse (0102) and one of the igniter mixtures found in chapter 3. (For example, several spoonfuls of Sugar-Chlorate Mixture (0201) are placed in a nonabsorbent wrapping material. Fuse cord is buried in the center of the igniter mixture and the fuse is taped to the wrapping material. This assembly is placed directly on the gelled

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gasoline. Delay times are determined by the length of fuse. Suitable delay mechanisms are given in chapter 5 for delay times longer than those practical with fuse cord.)

(2) Gelled gasoline should not ordinarily be used with a delay longer than one hour because gasoline evaporates and this can reduce its effectiveness.

(3) The destructive effect of gelled gasoline is increased when charcoal is added. The charcoal will readily ignite and the persistent fire from the charcoal will outlast the burning gasoline. It is recommended that at least one quart of gelled gasoline be used to ignite heavy wooden structures and large wooden sections. A minimum of one-half quart is recommended for wooden structures of small cross section.

Note. All of the chemicals used for the gelling process *must* be added in a *liquid* state. Many of the chemicals solidify at near freezing temperatures (32° F.) and uniform gels are difficult to produce at these temperatures.

0303. GELLED GASOLINE (IMPROVISED THICKENERS)

0303.1 LYE SYSTEMS

(1) This item consists of gasoline which is gelled by the addition of certain ingredients that are locally available. The following eight basic systems will produce gelled gasoline and are easily prepared: Lye systems, Lye-alcohol systems, Lye-balsam systems, Soap-alcohol systems, Egg system, Latex system, Wax systems, and Animal blood systems. These systems are discussed in the subparagraphs under 0303.

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(2) These incendiaries can be directly initiated by a match flame. However, any igniter listed in chapter 3 can be used in conjunction with specific delay mechanisms given in chapter 5 for delayed ignition.

(3) Gelled gasoline incendiary is readily ignited, long burning and is suitable for setting fire to large wooden structures and other large combustible targets. It adheres to objects, even on vertical surfaces.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Used for*	*Common source*
Gasoline	60	Motor fuel	Gas stations or motor vehicles.
Lye	2 (flake) or 1 (powder).	Drain cleaner, making of soap, etc.	Food and drug stores, soap factories.
Water	1 or 2	(Always use about same amount as dry lye).	
Rosin powder.	15	Paint or varnish, Naval supply, industrial uses.	Food and drug stores, pine tree extract, paint and varnish factories.

Two air-tight containers
Spoon or stick for stirring

Note. Lye is also known as caustic soda or sodium hydroxide. Allow for strength of lye; if only 50% (as in Drano), use twice the amount indicated above. Castor oil can be substituted for the rosin. Potassium hydroxide (caustic potash, potassa) may be used in place of lye.

c. Preparation.

(1) Measure the required quantity of gasoline and place in a clean container.

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Caution: **Keep material away from open flames.**

(2) Break the rosin into *small* pieces and add to the gasoline.

(3) Stir the mixture for about five minutes to disperse the rosin.

(4) In a separate container dissolve the lye in water.

Caution: **Add lye to water slowly. Do not prepare this solution in an aluminum con-**

tainer.

(5) Add this solution to the gasoline mixture and stir until mixture thickens (about one minute).

(6) The mixture will thicken to a very firm butter paste within one to two days. The mixture can be thinned, if desired, by mixing in additional gasoline. Store in an air-tight container until ready to use.

d. Alternate Preparation Using Pyrethrum Extract Instead of Rosin.

(1) Replace rosin by the following:

Ingredient	Parts by volume	Used for	Common source
Pyrethrum extract (20%).	18	Insecticide, medicine.	Hardware stores, graden supply, drug stores.

(2) Measure 78 parts by volume of gasoline and place in a clean container.

***Caution:* Keep material away from open flames.**

(3) Dissolve the pyrethrum extract in the gasoline by stirring.

(4) In another container dissolve the lye in water.

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***Caution:* Add lye to water slowly. Do not prepare this solution in an aluminum container.**

(5) Add 4 parts by volume of the lye solution to the gasoline mixture.

(6) Stir every 15 minutes until gel forms. Store in an air-tight container until ready to use.

e. Application

(1) To use gelled gasoline most effectively, it should be spread out over the surface of the material to be burned. This will start a large area burning at once. A match can be used to directly initiate this incendiary. A short time delay in ignition can be obtained by combining Fuse Cord (0101) or Improvised String Fuse (0102) and one of the igniter mixtures found in chapter 3. (For example, several spoonfuls of Sugar-Chlorate Mixture (0201) are placed in a nonabsorbent wrapping material. Fuse cord is buried in the center of the igniter mixture and the fuse is taped to the wrapping material. This assembly is placed directly on the gelled gasoline. Delay times are determined by the length of fuse. Suitable delay mechanisms are given in chapter 5 for delay times longer than those practical with fuse cord.)

(2) Gelled gasoline should not ordinarily be used with a delay longer than one hour because gasoline evaporates and this can reduce its effectiveness.

(3) The destructive effect of gelled gasoline is increased when charcoal is added. The charcoal will readily ignite and the persistent

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fire from the charcoal will outlast the burning gasoline. It is recommended that at least one quart of gelled gasoline be used to ignite heavy wooden structures and large wooden sections. A minimum of one-half quart is recommended for wooden structures of small cross section.

0303.2 LYE-ALCOHOL SYSTEMS

a. Description. See Paragraph 0303.1.

b. Material and Equipment.

Ingredient	Parts by volume	Used for	Common source
Gasoline	58	Motor fuel	Gas stations or motor vehicles.
Lye	2 (flake) or 1 (powder).	Drain cleaner, making of soap.	Food and drug stores, soap factories.
Water	1 or 2	(Always use about the same amount as dry lye).	
Ethyl alcohol.	3	Whiskey	Liquor stores.
Tallow	14	Food	Fat extracted from solid fat or suet of cattle, sheep, or horses.

Spoon or stick for stirring
Two air-tight containers

Note. Lye is also known as caustic soda or sodium hydroxide. Allow for strength of lye. If only 50% (as in Drano), use twice the amount indicated above. Methyl (wood) alcohol, isopropyl (rubbing) alcohol or antifreeze product can be substituted for whiskey, but their use produces softer gels. Potassium hydroxide (caustic potash, potassa) may be used in place of lye.

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(1) The following can be substituted for the tallow in order of preference:

(*a*) Wool grease (lanolin) (very good)—fat extracted from sheep wool.

(*b*) Castor oil (good).

(*c*) Any vegetable oil (corn, cottonseed, peanut, linseed, etc.).

(*d*) Any fish oil.

(*e*) Butter or oleo margarine.

(2) When using substitutes (1)(*c*) and (*e*) above, it will be necessary to double the recom-

mended amount of fat and of the lye solution for satisfactory thickening.

c. Preparation.

(1) Measure out the appropriate amount of gasoline and place in a clean container.

***Caution:* Keep material away from open flames.**

(2) Add the tallow to the gasoline and stir for about one-half minute to dissolve the tallow.

(3) Add the alcohol to the mixture.

(4) In another container dissolve the lye in water.

***Caution:* Add lye to water slowly. Do not prepare this solution in an aluminum container.**

(5) Add the lye solution to the gasoline mixture and stir occasionally until the mixture thickens (about one-half hour).

(6) The mixture will thicken to a very firm butter paste in one to two days. The mixture can be thinned, if desired, by mixing in additional gasoline. Store in an air-tight container until ready to use.

d. Application. See paragraph 0303.1.

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0303.3 LYE-BALSAM SYSTEMS

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Used for*	*Common source*
Gasoline	80	Motor fuel	Gas stations or motor vehicles.
Either: Copaiba balsam Copaiba resin Jesuits' balsam.	14	Medicine, varnish, odor fixative.	Drug stores, varnish factories, perfume processors, natural oleoresin.
Or: Tolu balsam Tolu resin Thomas balsam.	14	Medicine, perfume, confectionery, fumigant, chewing gum.	Drug stores, perfume processors, candy manufacturers.
Lye	3	Drain cleaner, making of soap.	Food and drug stores, soap factories.
Water	3		

Spoon or stick for stirring

Two air-tight containers

Note. Lye is also known as caustic soda or sodium hydroxide. Allow for the strength of the lye. If only 50% (as in Drano), use twice the amount indicated above. Potassium hydroxide (caustic potash, potassa) may be used in place of lye.

c. Preparation.

(1) Dissolve the lye in water using a clean container.

***Caution:* Add lye to water slowly. Do not prepare this solution in an aluminum container.**

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(2) Stir gasoline and copaiba balsam in another clean container.

(3) Add the saturated lye solution to the gasoline mixture and stir until the gel forms. Store in an air-tight container until ready to use.

Note. Increase the lye solution to 10 parts by volume (5 parts lye, 5 parts water) if the gasoline does not thicken.

d. Application. See paragraph 0303.1.

0303.4 SOAP-ALCOHOL SYSTEMS

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Used for*	*Common source*
Gasoline	36	Motor fuel	Gas stations or motor vehicles.
Ethyl alcohol.	1	Whiskey	Liquor stores
Laundry soap.	20 (powder) or 28 (flake).	Washing	Food stores

Air-tight container

Spoon or stick for stirring

Note. Methyl (wood) or isoprophyl (rubbing) alcohols can be subetituted for the ethyl alcohol. When a stronger alcohol (150 proof) or one of the dry alcohol subetitutes is used, add an amount of water to make the concentration 50% by volume. (The *percent* alcohol is equal to ½ of the *proof*—150 proof is 75% alcohol.)

(1) Unless the word *soap* actually appears somewhere on the container or wrapper (at retail store level), a washing compound may be assumed to be a synthetic detergent. Soaps

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react with mineral salts in hard water to form a sticky insoluble scum while synthetic detergents do not. Synthetic detergents cannot be used.

(2) The following is a list of commercially available soap products (at retail store level):

Name	*Manufacturer*
Ivory Snow	Proctor and Gamble
Ivory Flakes	Proctor and Gamble
Lux Flakes	Lever Brothers
Chiffon Flakes	Armour
Palmolive Bar Soap	Colgate-Palmolive
Sweetheart Bar Soap	Manhattan Soap Company
Octagon Bar Soap	Colgate-Palmolive

(3) Home prepared bar soaps may be used in place of purchased bar soaps.

c. Preparation.

(1) Measure out the appropriate amount of gasoline and place in a clean container.

Caution: **Keep material away from open flames.**

(2) Add the alcohol to the gasoline.

(3) Add the soap powder to the gasoline-alcohol mixture, and stir occasionally until the mixture thickens (about 15 minutes).

(4) The mixture will thicken to a very firm butter paste in one to two days. It can be thinned, if desired, by mixing in additional gasoline. Store in an air-tight container until ready to use.

d. Application. See paragraph 0303.1.

0303.5 EGG SYSTEM [66]

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Chemical name*	*Used for*	*Common source*
Gasoline	85		Motor fuel	Gas stations or motor vehicles.
Egg whites (chicken, ostrich, duck.	14		Food, industrial processes.	Food stores, farms.
Use any one of the following additives:				
Table salt	1	Sodium chloride	Food, industrial processes.	Sea water, natural brine, food stores.
Ground coffee (not decaffeinized).	3		Beverage	Food stores, coffee processors.
Leaf tea	3		Beverage	Cacao trees, food stores.
Sugar	2	Sucrose	Sweetening foods, industrial processes.	Sugar cane, food stores.
Borax	2	Sodium tetraborate decahydrate.	Washing aid, industrial processes.	Natural in some areas, food stores.
Saltpeter (Niter).	1	Potassium nitrate.	Pyrotechnics, explosives, matches, medicine.	Natural deposits, drug stores.
Epsom salts	1	Mganesium sulfate heptahydrate.	Medicine, mineral water, industrial processes.	Natural deposits, Kieserite, drug and food stores.
Washing soda (sal soda).	2	Sodium carbonate decahydrate.	Washing cleanser, medicine, photography.	Food, drug, and photo supply stores.
Baking soda	2	Sodium bicarbonate.	Baking effervescent salts, beverages, mineral waters, medicine, industrial processes.	Food and drug stores
Aspirin (crushed).	2	Acetylsalicylic acid.	Medicine	Food and drug stores.

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Spoon or stick for stirring
Two air-tight containers

c. Preparation.

(1) Separate the egg white from the yolk as follows:

(a) *Method 1.* Crack the egg at approximately the center. Allow the egg white to drain into a clean container. When most of the egg white has drained off, flip the yellow egg yolk from one-half shell to the other, each time allowing the egg white to drain into the container. Transfer the egg white to a capped jar for storage or directly into the container being used for the gelled flame

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fuel. Discard the egg yolk. Repeat the process with each egg. Do not get the yellow egg yolk mixed into the egg white. If egg yolk gets into the egg white, discard the egg.

(b) *Method 2.* Crack the egg and transfer (CAREFULLY SO AS TO AVOID BREAKING THE YOLK) the egg to a shallow dish. Tilt the dish slowly and pour off the egg white into a suitable container while holding back the yellow egg yolk with a flat piece of wood, knife blade, or fingers. Transfer the egg white to a capped jar for storage or directly to the container being used for the gelled flame fuel. Discard the egg yolk. Repeat the process with each egg being careful not to get yellow egg yolk mixed in with the egg white. If egg yolk

gets into egg white, discard the egg and wash the dish.

(2) Store egg white in an ice box, refrigerator, cave, cold running stream, or other cool area until ready to prepare the gelled flame fuel.

(3) Pour the egg white into a clean container.

(4) Add the gasoline.

Caution: **Keep material away from open flames.**

(5) Add the table salt (or one of its substitutes) and stir until the gel forms (about 5–10 minutes). Use within 24 hours. Thicker gelled flame fuels can be obtained by—

(*a*) Reducing the gasoline content to 80 parts by volume (NO LOWER); or

(*b*) Putting the capped jars in hot (65° C., 149° F.) water for ½ hour and then letting

them cool to ambient temperature. (DO NOT HEAT THE GELLED FUEL CONTAINING COFFEE.)

d. Application. See paragraph 0303.1.

0303.6 LATEX SYSTEM

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Used for*	*Common source*
Gasoline	92	Motor fuel	Gas stations or motor vehicles.
Either:			
Latex commercial or natural.	7	Paints, adhesives, rubber products.	Natural from tree or plant, rubber cement, general stores.
Or:			
Guayule Gutta percha Balata.	7	Wire insulation, waterproofing, machinery belts, golf ball covers, gaskets.	Coagulated and dried latex, rubber industry.
Any one of the following:			
Dilute acetic acid (vinegar).	1	Salad dressing, developing photographic films.	Food stores, fermented apple cider or wine, photography supply.
Sulfuric acid, battery acid (oil of vitriol).	1	Storage batteries, material processing.	Motor vehicles, industrial plants.
Hydrochloric acid 1 (muriatic acid).	1	Petroleum wells, pickling and metal cleaning, industrial processes.	Hardware stores, industrial plants.
Air-tight container			
Spoon or stick for stirring			

Caution: **Sulfuric acid and hydrochloric acid will burn skin and ruin clothing. The fumes will irritate nose passages, lungs and eyes. Wash with large quantities of water upon contact.**

c. Preparation.

(1) Commercial rubber latex may be used without further treatments before adding it to gasoline.

(2) Natural rubber latex will coagulate (form lumps) as it comes from the plant. Strain off the thick part for use in flame fuel. If the rubber latex does not form lumps, add a small amount of acid to coagulate the latex and use the rubbery lump for gelling. It is best to air-dry the wet lumps before adding them to gasoline.

(*a*) *Using commercial rubber latex.*

1. Place the latex and the gasoline in the container to be used for the gelled gasoline and stir.

Caution: **Keep material away from open flames.**

2. Add the vinegar (or other acid) to the liquid in the container and stir again until the gel forms. Store in an air-tight container until ready to use.

Note. Use gelled gasoline as soon as possible because it becomes thinner on standing. If the gel is too thin, reduce the gasoline content (but not below 85% by volume).

3. Natural rubber latex coagulates readily. If acids are not available, use one volume of

acid salt (alum, sulfates and chlorides other than sodium and potassium). The formic acid content of crushed red ants will coagulate natural rubber latex.

(*b*) *Using natural rubber latex.*

80 parts by volume of gasoline.

20 parts by volume of coagulated or dried rubber.

Let the rubber lump soak in the gasoline in a closed container two or three days until a gelled mass is obtained. Prepare the gelled gasoline using the above formulation. This gelled gasoline should be used as soon as possible after it has thickened sufficiently.

d. Application. See paragraph 0303.1.

0303.7 WAX SYSTEMS

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	*Parts by volume*	*Used for*	*Common source*
Gasoline	80	Motor fuel	Gas stations or motor vehicles.
Any one of the following waxes:			
Ozocerite mineral wax fossil wax ceresin wax.	20	Leather polish, sealing wax, candles crayons, waxed paper, textile sizing.	Natural deposits, general and department stores.
Beeswax	20	Furniture and floor waxes, artificial fruit and flowers, wax paper, candles.	Honeycomb from bees, general and department stores.

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Ingredient	*Part by volume*	*Used for*	*Common source*
Bayberry wax myrtle wax.	20	Candles, soaps, leather polish, medicine.	Natural from myrica berries, general, department, and drug stores.
Lye	0.5	Drain cleaner, making of soap.	Food and drug stores, soap factories.

Two air-tight containers
Spoon or stick for stirring

***Caution:* Lye causes severe burns to eyes.**

Note. Lye is also known as caustic soda or sodium hydroxide. Allow for strength of lye. If only 50% (as in Drano), use twice the amount indicated above. Potassium hydroxide (caustic potash, potassa) may be used in place of lye.

c. Preparation.

(1) *Wax from natural sources.*

(*a*) Plants and berries are potential sources of natural waxes. Place the plants and/or berries in boiling water. The natural waxes will melt. Let the water cool, and the natural waxes will form a solid layer on the water surface. Skim off the wax and let it dry.

(*b*) Natural waxes which have suspended matter should be melted and screened through a cloth.

(2) *Gel from gasoline and wax.*

(*a*) Put the gasoline in a clean container.

***Caution:* Keep material away from open flames.**

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(*b*) Melt the wax and pour it into the gasoline container.

(*c*) Tightly cap the container and place it in hot water (sufficiently hot so that a small piece of wax will melt on the surface).

(*d*) When the wax has dissolved in the gasoline, place the capped container in a warm water bath and permit it to cool slowly to air temperature.

(*e*) If a solid paste of gel does not form, add another 10 parts by volume of melted wax and repeat (*b*), (*c*), and (*d*) above.

(*f*) Continue adding wax (up to 40 parts by volume) as before until a paste or gel is formed. If no paste forms at 80 parts by volume of gasoline and 40 parts by volume of melted wax, the wax is not satisfactory for gelled gasolines and may be used only in combination with alkali.

(3) *Gel from gasoline, wax and alkali.*

70 parts by volume of gasoline
29.5 parts by volume of melted wax
0.5 parts by volume of staurated lye solution

(*a*) Prepare the saturated lye solution by *carefully* adding one volume of lye (or two volumes of Drano) to one volume of water and stir with a glass rod or wooden stick until the lye is dissolved.

***Caution:* Lye causes severe burns to eyes. Add the lye to the water slowly. Let cool to room temperature and pour off the saturated liquid solution. Do not prepare this solution in an aluminum container.**

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(*b*) Prepare the gasoline-wax solution according to the method described above.

(*c*) After the solution has cooled for about 15 minutes, CAUTIOUSLY loosen the cap, remove it and add the saturated lye solution.

(*d*) Stir about every five minutes until a gel forms. If the gel is not thick enough, remelt with another 5 parts by volume of wax and 0.1 part by volume of saturated lye solution. Stir contents as before. Store in an air-tight container until ready to use.

Note. In addition to the listed waxes, the following may be used: candelilla wax, carnauba (Brazil) wax, Chinese (insect) wax, Japan (sumac) wax, montan (lignite) wax, and palm wax.

d. Application. See paragraph 0303.1.

0303.8 ANIMAL BLOOD SYSTEMS

a. Description. See paragraph 0303.1.

b. Material and Equipment.

Ingredient	Parts by volume	Chemical name	Used for	Common source
Gasoline	68		Motor fuel	Gas stations or motor vehicles.
Animal blood (sheep, cow, hog, dog, etc.).	30		Food, medicine.	Slaughter houses, natural habitat.
Any one of the following:				
Coffee (not decaffeinized).	2		Food, caffeine source, beverage.	Coffee processors, food stores.
Leaf tea	2		Food, beverage.	Tea processors, food stores.

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Ingredient	Parts by volume	Chemical name	Used for	Common source
Lime	2	Calcium oxide.	Mortar, plaster, medicine, ceramics, industrial processes.	From calcium carbonate, hardware and drug stores.
Baking soda	2	Sodium bicarbonate.	Baking, beverages, medicine, industrial processes.	Food and drug stores.
Epsom salts.	2	Magnesium sulfate heptahydrate.	Medicine, industrial processes, mineral water.	Natural deposits, drug and food stores.

Two air-tight containers
Spoon or stick for stirring

c. Preparation.

(1) *Animal blood serum.*

(*a*) Slit animal's throat by jugular vein. Hang upside down to drain.

(*b*) Place coagulated (lumpy) blood in a cloth or on a screen and catch the red fluid (serum) which drains through.

(*c*) Store in a cool place if possible.

Caution: **Animal blood can cause infections. Do not get aged animal blood or the serum into an open cut.**

(2) *Preparation of gelled gasoline.*

(*a*) Pour the animal bolod serum into a clean container and add the gasoline.

Caution: **Keep material away from open flames.**

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(*b*) Add the lime and stir the mixture for a few minutes until a firm gel forms. Store in an air-tight container until ready to use.

Note. Egg white may be substituted for up to ½ of the animal blood serum.

d. Application. See paragraph 0303.1.

0304. PARAFFIN-SAWDUST

a. Description.

(1) This item consists of a mixture of paraffin wax and sawdust. It is easily prepared and safe to carry. It is used to ignite wooden structures including heavy beams and timbers. It will also ignite paper, rags and other tinder type materials to build larger fires.

(2) This incendiary can be safely ignited by a match flame. However, any igniter listed in chapter 3 can be used in conjunction with specific delay mechanisms in chapter 5 for delayed ignition of this incendiary.

(3) All or part of the paraffin wax may be replaced by beeswax but *not* by vegetable or animal fats or greases.

b. Material and Equipment.

Paraffin wax, beeswax, or wax obtained by melting candles.
Sawdust.
Source of heat (stove, hot plate).
Pot.
Spoon or stick for stirring.

c. Preparation.

(1) Put enough wax in the pot so that it is about half full.

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(2) Heat the pot on a stove or hot plate until the wax melts.

(3) Remove the heated pot from the stove or hot plate and shut off the source of heat. Add the sawdust to the melted wax until the pot is nearly full. Stir the mixture with a spoon or stick for a few minutes, being sure there is no layer of wax at the bottom of the pot which has not been mixed with the sawdust.

(4) While the mixture is in a fluid state, pour it into a waxed paper carton or other container. Upon cooling, the wax mixture will harden and take the shape of the container. The mixture can be stored for months without losing its effectiveness. If it becomes wet, it will be effective again when it is dried.

(5) A less effective incendiary may be made by melting some paraffin or beeswax, dipping sheets of paper in the molten wax for a few seconds, and removing the paper to let the wax harden. This waxed paper lights readily

from a match. Although not as hot or persistent or the paraffin-sawdust mixture, the waxed paper is an excellent incendiary and may be substituted in many instances for initiating readily ignitable materials. The paper may be wadded up, folded, or torn into strips.

d. Application.

(1) Place about a quart of the mixture in a paper bag and put the bag down on the object to be burned. A match may be used to ignite the bag which will then ignite the paraffin-sawdust mixture. The fire starts very slowly so there

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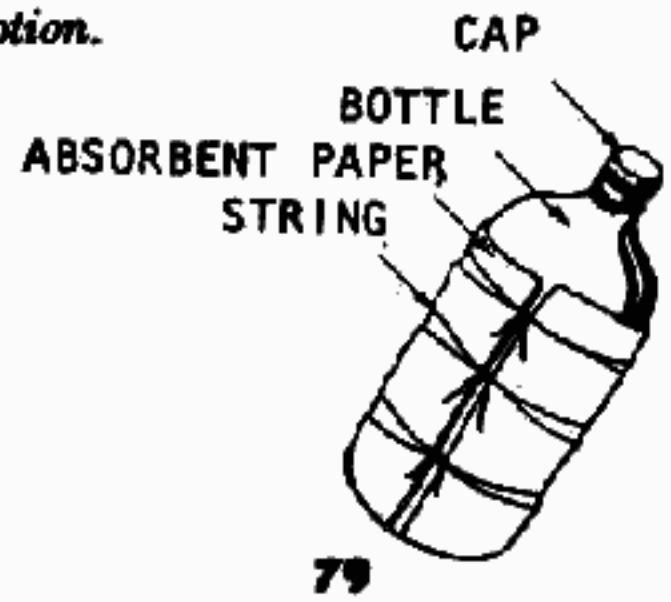
is no hazard involved, and it usually takes two or three minutes before the paraffin-sawdust mixture is burning strongly. This, of course, is a disadvantage where a hot fire is required quickly. Once started, however, this mixture burns vigorously because the paraffin itself gives a fairly hot flame and the sawdust acts like charcoal to increase the destructive effect.

(2) Where very large wooden beams or structures are to be burned use more of the mixture. A bag containing two or three quarts will be enough to set fire to almost any object on which paraffin-sawdust mixture can be used effectively.

(3) To be most effective on wood structures, this mixture should be in a pile, *never* spread out in a thin layer. If possible, place it under the object. When placing the incendiary in a packing box or in a room, place it in a corner.

0305. FIRE-BOTTLE (IMPACT IGNITION)

a. Description.



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This item consists of a glass bottle containing gasoline and concentrated sulfuric acid. The exterior of the bottle is wrapped with a rag or absorbent paper. Just before use, the rag is soaked with a saturated solution of granulated sugar and potassium chlorate. Thrown against hard-surfaced targets such as tanks, automotive vehicles or railroad boxcars, this fire bottle is a very effective incendiary.

b. Material and Equipment.

Concentrated sulfuric acid (para 0103).
Gasoline.
Potassium chlorate (powdered).
Sugar (granulated).
Jar or bottle, with cap or stopper (½ pint).
Cloth or absorbent paper.
Jar or bottle, with cap or stopper (1 quart).
String or tape.
Heat resistant glass or porcelain pot (1 pint capacity).
Heat source.
Glass funnel.
Spoon.
Small container for measuring.

c. Preparation.

(1) Using the funnel, pour the gasoline into the quart bottle until approximately two-thirds full.

Caution: Keep this material away from open flames.

(2) Slowly add concentrated sulfuric acid through the funnel to the gasoline in the bottle and fill the bottle to within one inch of the top. The funnel must be used to direct the concentrated acid into the gasoline in the center

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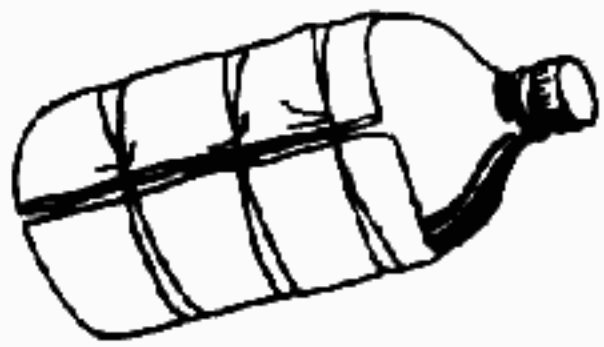
of the bottle. Stopper or cap the bottle securely.

Note. If only battery-grade sulfuric acid is available, it must be concentrated. See instructions under paragraph 0103.

(3) Flush the tightly capped bottle with water to remove any gasoline or acid adhering to the outside surface and dry the bottle. This *must* be done to avoid accidental combustion during the following steps.

(4) Wrap a clean cloth or several sheets of absorbent paper around the bottle. Fasten with strings or rubber bands.



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(5) Prepare a saturated solution of granulated sugar and potassium chlorate in water as directed below.
(6) Add six measures of water to the porcelain pot and dry the measuring container with a clean rag or paper towel.
(7) Bring the water to a boil.
(8) Using a clean, dry spoon, place granulated sugar in the measuring container and add one and one-half measures of sugar to the boiling water.
(9) Wipe the spoon with a clean rag or paper towel and place one measure of potassium chlorate into the boiling sugar water.
(10) Remove the pot of boiling mixture immediately from the heat source and shut off heat source.
(11) When the solution is cool, pour it into the small ½ pint bottle using the glass funnel and cap tightly.
(12) Flush this bottle with water to remove any solution or crystals adhering to the outside surface and dry the bottle. When the crystals settle, there should be about ⅓ liquid above the crystals.

Caution: **Store this bottle separately from the other bottle containing gasoline and concentrated sulfuric acid.**

d. Application.

(1) Just prior to actual use, shake the bottle containing the sugar-potassium chlorate crystals and pour onto the cloth or paper wrapped around the gasoline-acid bottle. The fire bottle can be used while the cloth is still wet or

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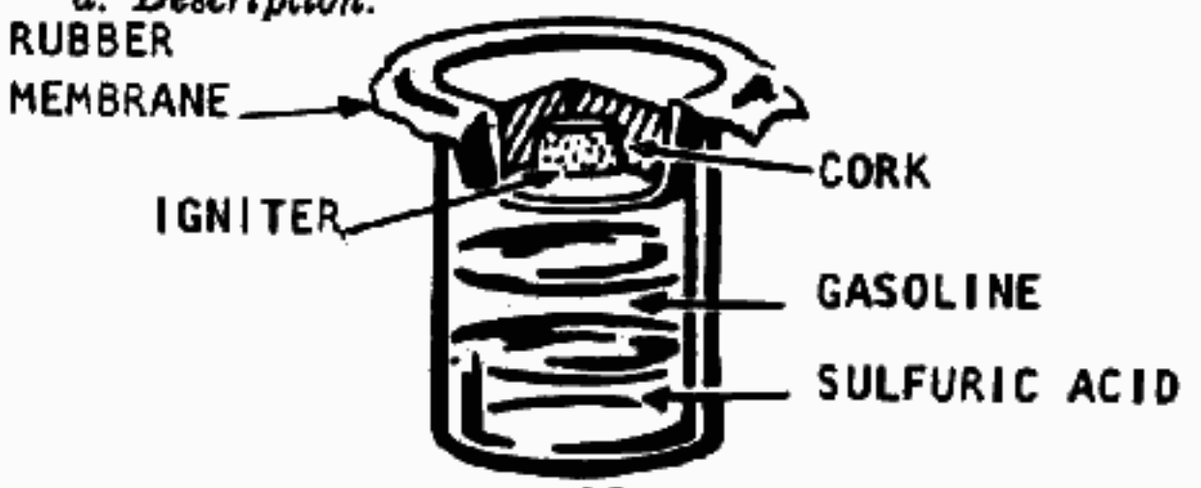
after it has dried. However when dry, the sugar-potassium chlorate mixture is very sensitive to sparks, open flame, bumping and scraping. In the dry condition the bottle should be handled carefully.

(2) The fire bottle should be gripped in one hand and thrown like a hand grenade. Upon impact with a metallic or other hard surface, the bottle will break and the sugar-potassium chlorate will react with the sulfuric acid. This reaction ignites the gasoline which will engulf the target area in flames.

0306. FIRE BOTTLE (DELAY IGNITION)

a. Description.



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(1) This item consists of a bottle of gasoline and concentrated sulfuric acid which is ignited by the chemical reaction of the acid with Sugar-Chlorate Igniter (0201). A delay feature is incorporated in this incendiary. The amount of delay is determined by time it takes the sulfuric acid to corrode a rubber membrane and react with the igniter mix. Immediate ignition may also be achieved by breaking the bottle and allowing the ingredients to mix.
(2) Prepared fire bottles are stored upright. This allows the heavier acid to lay on the bottom, with the gasoline on top. When put in use, the bottle is inverted, allowing the acid to come in contact with the rubber membrane and to begin corroding it.

b. Material and Equipment.

Wide mouth bottle.
Cork or rubber stopper (must fit snugly in bottle).
Sheet rubber on rubber membrane.
Sugar-Chlorate Igniter (0201).
Concentrated Sulfuric Acid (0103).
Gasoline.

c. Preparation.

(1) Cut or drill a cavity on the bottom of the cork big enough to hold at least two teaspoonfuls of sugar-chlorate igniter. Be careful not to break through the cork. If the hole does go all the way through, it must be sealed with another smaller cork.

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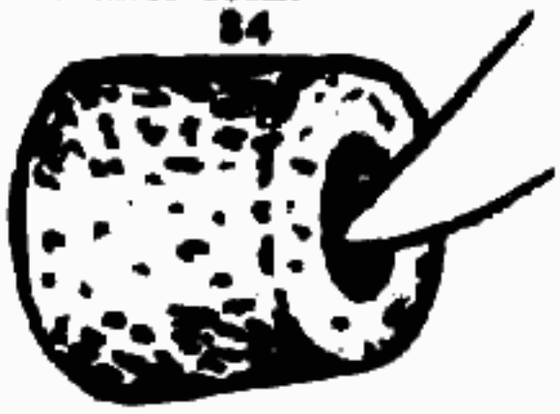

(2) Fill the bottle with a 50/50 concentration of gasoline and sulfuric acid. Pour the gasoline in first, then add the sulfuric acid carefully, making certain not to splash acid on the skin or in the eyes.

Note. If only battery grade sulfuric acid is available it must be concentrated before it can be used. See paragraph 0103 for details of concentration process.

(3) Fill the hole in the cork with Sugar-Chlorate Igniter (0201). Cover the side of the cork containing the igniter with a piece of thin rubber membrane and then force the cork into the gasoline-acid filled bottle. Take care to prevent any of the igniter mix from falling into the jar.

d. Alternate Method of Preparation.

(1) Drill or cut a hole all the way through the cork.
(2) Fill the bottle with gasoline and acid as described above.
(3) Place the rubber membrane over the cork and install in the bottle. Make certain that cork is fitted tightly and rubber membrane fully covers the inner portion of the bottle.

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(4) Fill the hole in the cork with igniter mixture as before and install a small cork in the hole covering the igniter mixture.

e. Application.

(1) To start the delay working invert the bottle. The acid will begin corroding the rubber membrane. When the acid breaks through, it will react violently and either break the bottle or blow out the cork stopper and ignite the gasoline.
(2) The Delay Fire Bottle works well on readily ignited materials where the scattering of the burning gasoline will start a number of fires at once. To ignite wooden structures, preparation such as piling up of flammable tinder and kindling is required.
(3) The delay time for initiation of the gasoline is slowed down in cold weather and may be stopped if the acid freezes. Check the delay time by testing the acid with the identical thickness rubber membrane at the temperature of expected use. Always use concentrated sulfuric acid.

0307. THERMITE

a. Description.

(1) Thermite is composed of magnetic iron flakes and aluminum powder. Thermite may be obtained as a manufactured item or may be improvised for use in welding machinery parts together and burning holes in metal structures. The termite reaction is initiated by strong heat and therefore cannot be directly ignited with a safety fuse or match.

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The following igniters, found in chapter 3, may be used to initiate thermite: Powdered Aluminum—Sulfur Pellets (0207), Magnesium Powder—Barium Peroxide Igniter (0210), and Subigniter for Thermite (0211).

(2) Thermite is very safe to handle and transport because of its high ignition temperature. It burns well in cold and windy weather. Thermite will penetrate a sealed metal container and ignite the contents. It may be easily improvised if aluminum powder and iron oxide particles of the proper size are available.

b. Material and Equipment.

Aluminum powder (no coarser than ground coffee).
Iron oxide flakes (Fe_3O_4—similar to coarse ground coffee).
Spoon or cup for measuring.
Jar or can with tight fitting lid.
Cardboard can with metal ends.

c. Preparation.

(1) Place three parts by volume of iron oxide and two parts by volume of aluminum powder into the jar. Leave enough empty space to facilitiate mixing.
(2) Tighten the lid on the jar, turn the jar on its side and slowly roll until the two powders are completely mixed. The mixture is now ready for use and may be stored for months in the sealed container.

d. Application.

(1) Thermite is used to attack metallic targets such as transformers, electric motors, file cabinets, gears, bearings, boilers, storage tanks

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and pipelines. In operation, the methods described below produce a quantity of molten metal that streams out the bottom of the unit. On contact with the target, the molten metal will cut through the outer metal casing and pour molten metal on the interior. Thermite is *not* recommended for use on moderate or heavy wooden structures or other applications where a persistent flame is required. Two basic techniques are described, one for burning holes in steel and the other for welding steel

parts together.

(*a*) *Burning holes.*

1. In order to penetrate a steel plate with the minimum quantity of thermite, the mass of ignited thermite must be held away from the target during the initial combustion period. This minimizes conductive heat loss (from the thermite to the target) during this period and results in the thermite attaining maximum combustion temperature. When that temperature is reached, the thermite is dropped onto the steel plate surface and a hole is burned through the plate. The following illustrates the method for burning a hole through a plate of ⅜ inch structural steel.

2. Cut a cardboard can (having metal ends) into two equal sections. Example of the type of cardboard container required are which contain household abrasive cleaners such as *AJAX, BON AMI* and *OLD DUTCH CLEANSER.*

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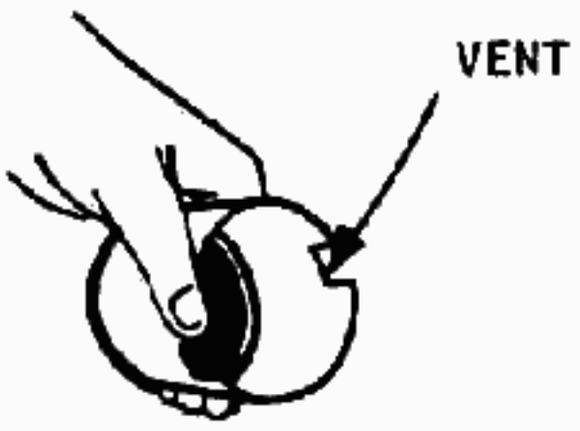
3. One section of the can trimmed to a height of 2 inches and two side vents are cut as shown below.



4. The other section is filled approximately ⅔ full with thermite. The thermite is then completely covered with one of the three above mentioned igniter materials to a depth of at least ¼ inch. Place the end of a length of Fuse Cord (0101) into the igniter mix, making certain that it does not extend into the thermite itself but ends in the center of the igniter mixture. Improvised String Fuse (0102) may be substituted for the Fuse Cord (0101) if desired.

5. The final assembly is constructed by placing the vented section, open face down, over the target area. The metallic end of this section is now facing up, away from the target surface. The section filled with thermite, igniter, and fuse is placed on top of the vented section. Both metal ends of the cardboard can are now touching.

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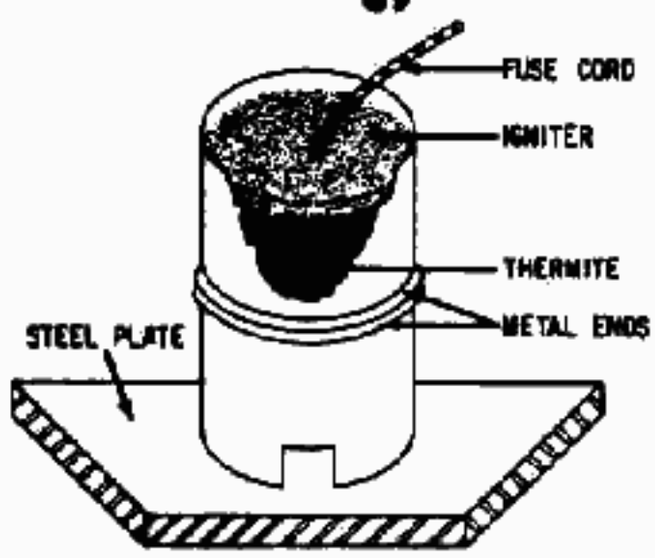

6. After ignition, the thermite burns a hole through the steel plate dropping extremely hot particles of molten slag into the interior of the steel container. The side vents cut in the bottom section of the can allow excess slag to run off and not close up the hole in the steel target.

(*b*) *Welding.*

1. A different method is employed when thermite is used to weld machinery components or plates together. The procedure is similar to that used for burning through steel except that the bottom stand-off is eliminated and the amount of thermite can be less than that used to burn through a ⅜ inch steel plate. The assembly is shown below.

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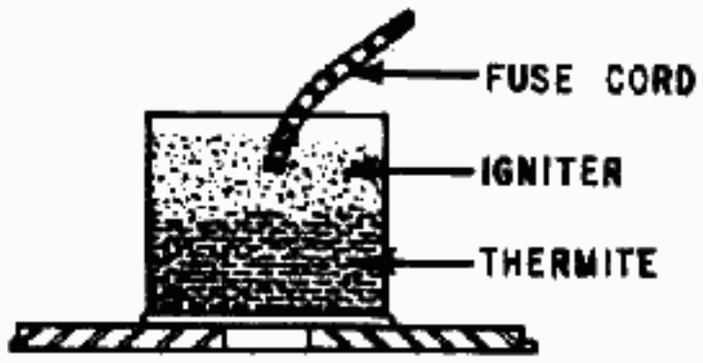

2. In this instance, heat is conducted from the thermite to the steel during the combustion period. Thus, the steel is heated to nearly the same temperature as the slag and a weld is effectively made.

Caution: **Never attempt to ignite thermite without at least a few seconds delay time because it burns so quickly and so hot that the user could be seriously burned if he were nearby when ignition took place.**

0308. FLAMMABLE LIQUIDS

a. Description. Flammable liquids are an excellent incendiary for starting fires with easily combustible material. They burn with a hot flame and have many

uses as incendiaries. Most of these liquids are readily available and they are easily ignited with a match. However, these liquids tend to flow off the target and their characteristic odor may cast suspicion on the person found carrying them.

b. Material and Equipment.

Can or bottle with tight fitting lid (minimum 1 pint capacity).

One of the following volatile liquids:

Gasoline	Cleaners naptha
Kerosene	Turpentine
Toluene or Toluol	Lighter fluid
Xylene or Xylol	Fuel oil
Benzene or Benzol	Alcohol

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c. Preparation. No preparation other than placing the liquid into an air-tight container for storage and transportation to the target is required.

d. Application. The most effective way to use flammable liquids is to pour at least a pint of the liquid on a pile of rags or sawdust which have been place in a corner of a packing box or other wooden object. This procedure keeps the liquid concentrated in a small area and gives a more persistent flame for igniting wooden objects. If small pieces of charcoal are available, they should be soaked with the flammable liquid and placed on the target. The charcoal will ignite and give a hot, persistent glow that is long lasting. After placing the flammable liquid on the target, throw a lighted match on a soaked area. Do not stand too close when this is done.

0309. INCENDIARY BRICK

a. Description.

(1) This incendiary is composed of potassium chlorate, sulfur, sugar, iron filings and wax. When properly made, it looks like an ordinary building brick and can be easily transported without detection. The incendiary brick will ignite wooden walls, floors, and many other combustible objects.

(2) This incendiary can be directly ignited by all igniters listed in chapter 3, coupled with a specific delay mechanism found in chapter 5. To ignite this incendiary with White Phosphorus Solution (0209), the solution must first

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be poured on absorbent paper and the paper placed on top of the brick.

b. Material and Equipment.

	Parts by volume
Potassium chlorate (powdered)	40
Sulfur (powdered)	15
Granulated sugar	20
Iron filings	10
Wax (beeswax or ordinary candle wax)	15

Spoon or stick
Brick mold
Red paint
Measuring cup or can
Double boiler
Heat source (hot plate or stove)

c. Preparation.

(1) Fill the bottom half of the double boiler with water and bring to a boil.

(2) Place the upper half of the boiler on the lower portion and add the wax, sulfur, granulated sugar, and iron filings in the proper amounts.

(3) Stir well to blend all the materials evenly.

(4) Remove the upper half of the double boiler from the lower portion and either shut off the heat source or move the upper section several feet from the fire.

Caution: **Extreme care should be exercised at this point because accidental ignition of the mixture is possible. Some means of extinguishing a fire should be at hand, a fire extinguisher or sand. It is important to keep face, hands, and clothing at a reasonably safe distance during the remainder of the preparation. A face shield and fireproof gloves are recommended.**

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(5) CAREFULLY add the required amount of potassium chlorate and again stir well to obtain a homogeneous mixture.

(6) Pour the mixture into a brick mold and set aside until it cools and hardens.

(7) When hard, remove the incendiary from the mold, and paint it red to simulate a normal building brick.

d. Application.

(1) When painted, the incendiary brick can be carried with normal construction materials and placed in or on combustible materials.

(2) A short time delay in ignition can be obtained by combining Fuse Cord (0101) or Improvised String Fuse (0102) and one of the igniter mixtures found in chapter 3. (For example, several spoonfuls of Sugar-Chlorate mixture (0201) are placed on the incendiary brick. Fuse cord is buried in the center of the igniter mixture and the fuse is taped to the brick. Delay times are determined by the length of the fuse. Suitable delay mechanisms are given in chapter 5 for delay times longer than those practical with fuse cord.)

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CHAPTER 5

DELAY MECHANISMS

0401. CIGARETTE

a. Description.

(1) This item consists of a bundle of matches wrapped around a lighted cigarette. It is placed directly on easily ignited material. Ignition occurs when the lighted portion of the burning cigarette reaches the match heads. This delay mechanism can be used to initiate all igniters listed in chapter 3 except Magnesium Powder—Barium Peroxide (0210) and Powdered Aluminum—Sulfur Pellets (0207). A cigarette delay directly ignites the following incendiaries: Napalm (0301), Gelled Gasoline (exotic thickeners) (0302), and Gelled Gasoline (improvised thickeners) (0303).

(2) The following *dry* tinder type materials may also be directly ignited by the cigarette delay mechanism: Straw, paper, hay, woodshavings and rags.

(3) Usually this delay will ignite in 15 to 20 minutes, depending on length of cigarette, make of cigarette, and force of air currents. A duplicate delay mechanism should be tested to determine delay time for various ambient conditions.

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(4) The cigarette must be placed so that the flame will travel horizontally or upward. A burning cigarette that is clamped or held will not burn past the point of confinement. Therefore, the cigarette should not contact any object other than matches.

b. Material and Equipment.

Cigarette.
Matches (wooden).
Match box.
String or tape.

c. Preparation.

(1) *Picket-fence delay.*

(*a*) Push one wooden match head into a cigarette a predetermined distance to obtain the approximate delay time.

(*b*) Tie or tape matches around the cigarette with the match heads at the same location as the first match in the cigarette.

(2) *Match box delay.*

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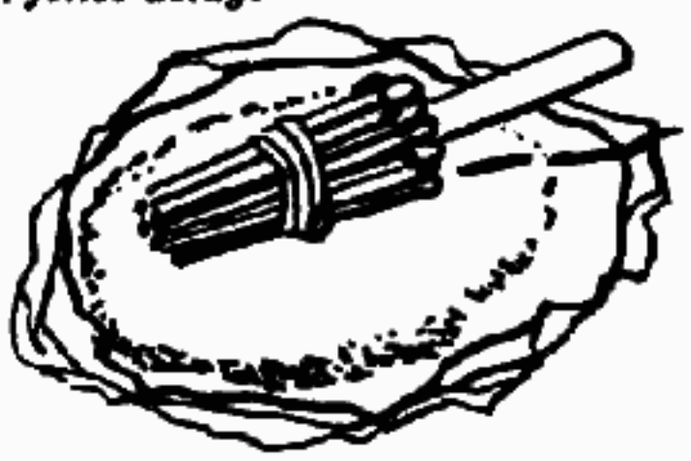
Tear out one end of the inner tray of a box of matches (the end next to the match heads). Push one match into the cigarette. *Insert* this cigarette into the bunch of matches and parallel to the matches at the center of the pack. Slide the tray out of the *inner* box, leaving the match heads and the cigarette exposed. The head of the match in the cigarette should be even with the exposed match heads.

d. Application.

(1) *Picket-fence delay.*



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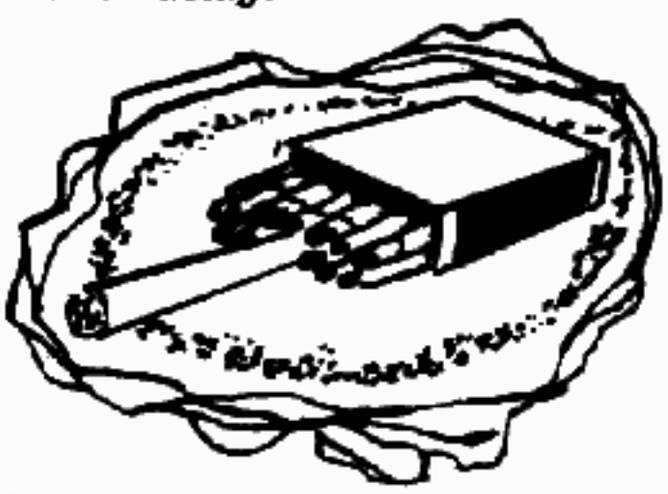
(*a*) Light the cigarette and place the delay mechanism on a pile of igniter mixture, paper, straw, or other dry tinder type material. Be sure that the portion of the cigarette between the lit end and the match heads is not touching anything.

(*b*) Pile tinder material all around the cigarette to enhance ignition when the match heads ignite.

(2) *Match box delay.*



(*a*) Place the delay so that the cigarette is horizontal and on top of the material to be ignited. Light the cigarette.

(*b*) Be sure ignitable material such as paper, straw, flammable solvents, or napalm is

placed close to the match heads. When using flammable solvents, light the cigarette away from the area of solvent fumes.

(c) To assure ignition of the target, sprinkle some igniter material on the combustible material. The match box delay is then placed on top of the igniter material.

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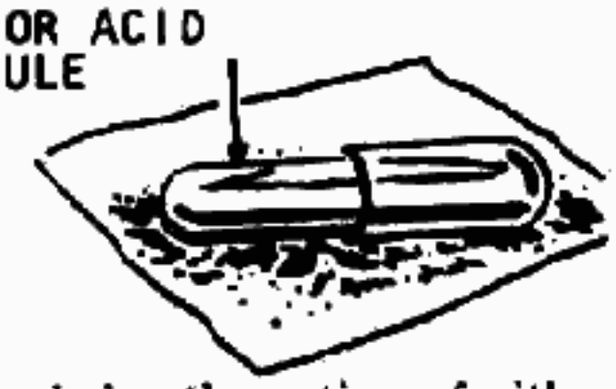
0402. GELATIN CAPSULE

a. Description.



Gelatin capsule delays work by the action of either water or concentrated sulfuric acid on the gelatin. When the liquid dissolves the gelatin, it contacts and reacts with an igniter mix. These delays can be used with various igniters, are easily prepared and easily carried. The disadvantage is that the delay times vary with temperature and they will not work at or below 32° F. Gelatin capsule delays will work with the following igniters:

(1) Water actuated igniters such as Sugar—Sodium Peroxide (0203), Silver Nitrate—Magnesium Powder (0208), and Aluminum Powder—Sodium Peroxide (0204).

(2) Concentrated sulfuric acid actuated igniters such as Sugar-Chlorate (0201), Fire Fudge (0202), Sugar—Sodium Peroxide (0203) Aluminum Powder—Sodium Peroxide (0204), Match Head (0205), and Silver Nitrate—Magnesium Powder (0208).

b. Material and Equipment.

Concentrated sulfuric acid or water.

Gelatin capsules (1 fluid ounce capacity).

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Igniter mixture.

Glass jar or bottle with glass or plastic stopper for carrying acid.

c. Preparation.

(1) Fill the gelatin capsule with either water or sulfuric acid, depending on which igniter is being used. Use a medicine dropper to fill the capsule. Wipe the outside of the capsule carefully and place it on a quantity of igniter mixture.

(2) Gelatin will slowly dissolve in either water or concentrated sulfuric acid, usually faster in water than in acid. Sulfuric acid should be handled carefully and only in glass or unchipped enamel containers.

d. Application.

(1) Fill a gelatin capsule with one of the igniter mixes listed under *Description* above. Once the liquid is added to the capsule, the next operations should be done quickly. Pile the igniter mixture on and around the capsule. Then place incendiary material in contact with the igniter mixture. (In damp weather this method should not be used with water activated igniters because premature ignition may be caused by humidity in the air.)

(2) Use the following method in damp weather. Fill a gelatin capsule with one of the igniter mixes listed above. Be sure that both halves of the capsule fit tightly and that no igniter mix is clinging to the outside of the capsule. Place the capsule in a shallow glass or porcelain dish filled with water or concentrated sulfuric acid, depending on which type of

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igniter mix is used. Make sure the capsule is touching one edge of the bowl and quickly pile incendiary material close to the capsule so that when the capsule ignites, the incendiary will also ignite.

(3) The gelatin capsule delays work slowly in cold weather and will not work at or below 32° F. Capsule thickness also affects delay time. In water at 77° F.. a delay time of approximately 20 minutes can be expected, while the same type of capsule in concentrated sulfuric acid at 77° F. will give a delay time of approximately one hour. At a temperature of 50° F., the same type of capsule will give a 6 to 8 hour delay time in water and about 24 hours delay time in concentrated sulfuric acid. Delay times become less accurate at lower temperatures.

(4) The above listed delay times are given for one type of gelatin capsule only. Various types of capsules will give various delay times. Therefore, always check delay times for the capsule to be used.

(5) The sulfuric acid must be concentrated. If only battery-grade sulfuric acid is available, it must be concentrated before use to a specific gravity of 1.835 by heating it in an enameled, heat resistant glass or porcelain pot until dense, white fumes appear. See paragraph 0103 for details.

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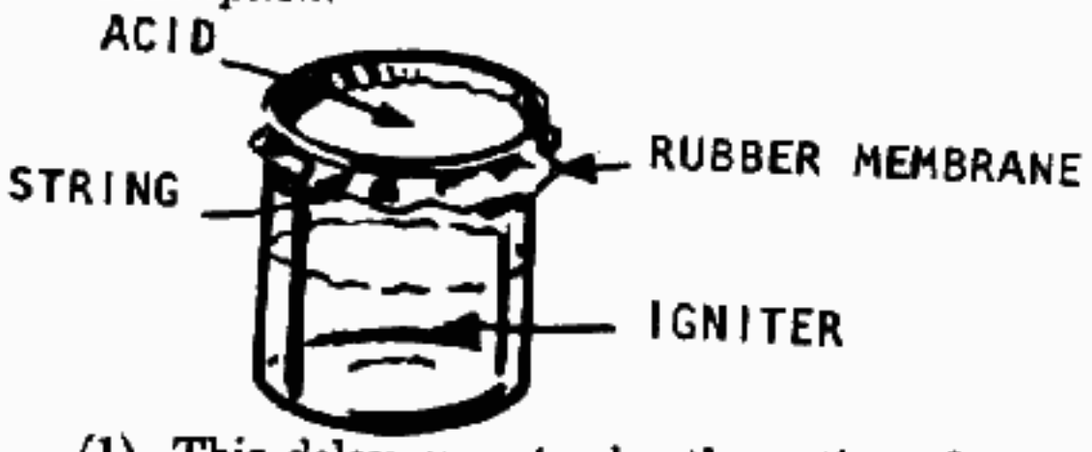
0403. RUBBER DIAPHRAGM

a. Description.



(1) This delay operates by the action of concentrated sulfuric acid on a thin rubber diaphragm. As the acid eats through the diaphragm, it drips onto the igniter mix and combustion results. This delay can be used to initiate the following igniters listed in chapter 3: Sugar-Chlorate (0201), Fire Fudge (0202), Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), Match Head (0205), Silver Nitrate—Magnesium Powder (0208), and Fire Bottle (0306).

(2) The delay does not burn or glow, a very desirable feature where premature detection may occur. The main disadvantages of this type of delay are—

(*a*) Delay time fluctuates with temperature changes.

(*b*) Delay is not reliable below 40° F.

(*c*) Sulfuric acid involves hazards to the operator.

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b. Material and Equipment.

Concentrated sulfuric acid.
Thin rubber (such as balloons or condoms).
String, tape, or rubber bands.
Glass jar with glass stopper for carrying acid.
Wide-mouthed jar or can (approximately 1 pint capacity).

c. Preparation.

(1) Fill the wide mouth container three-quarter full with any one of the following igniter materials:

Sugar-Chlorate (0201).
Fire Fudge (0202).
Sugar—Sodium Peroxide (0203).
Aluminum Powder—Sodium Peroxide (0204).
Match Head (0205).
Silver Nitrate—Magnesium Powder (0208).

(2) Place the rubber diaphragm over the open end of the container and leave it loose enough to sag slightly into the jar. Either tie in place or secure with a rubber band.

(3) Pour about 1 fluid ounce of concentrated sulfuric acid into a small glass jar with a glass stopper and seal tightly.

d. Application.

(1) Place the jar with the rubber membrane at the desired target. Pile the material to be ignited around this jar so that when the flames issue from the jar, they will ignite the incendiary materials. *Do not put any of this igniter material on the rubber membrane.* Pour the 1 fluid ounce of concentrated sulfuric acid onto the rubber membrane. When the acid penetrates the rubber and drips onto the

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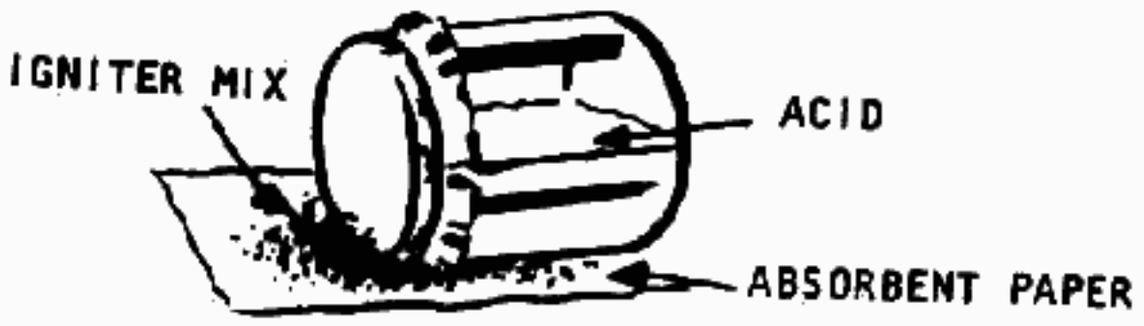
igniter mix, a chemical reaction occurs and combustion results.

(2) The time delay of this device depends on the kind and thickness of rubber used, and on the ambient temperature. Test a similar device before actual use on the target.

(3) Using a thin rubber membrane such as a condom at a temperature of 77° F., a delay time of 15 to 20 minutes is normal. This same delay when tested at 40° F. may take as long as eight hours to penetrate the rubber membrane. Do not use this delay at temperatures below 40° F.

(4) Another simple method of using this type of delay is to first fill a small jar half full of concentrated sulfuric acid. Tie or tape a rubber membrane over the open end of the jar. BE SURE NO ACID CAN LEAK OUT. Place the bottle on its side, on top of a small pile of igniter material which will ignite on contact with the acid. When the acid penetrates the membrane, combustion will occur as before. If thicker rubber is used, stretch the rubber tightly over the mouth of the jar. This will decrease the delay time because the acid will attack the stretched rubber more effectively.



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(5) A rubber glove may also be used as a membrane for this delay. Pour some concentrated sulfuric acid into the glove and suspend the glove over a pile of igniter material. When

the acid eats through the glove, it will drip onto the igniter and start a fire. A rubber glove will give a longer delay time than a condom because the material is thicker.

(6) The rubber membranes for use in this delay must be without pin holes or other imperfections. The sulfuric acid must be *concentrated*. If only battery-grade sulfuric acid is available, it must be concentrated before use to a specific gravity of 1.835 by heating it in an enameled, heat-resistant glass or porcelain pot until dense, white fumes appear. See paragraph 0103 for details.

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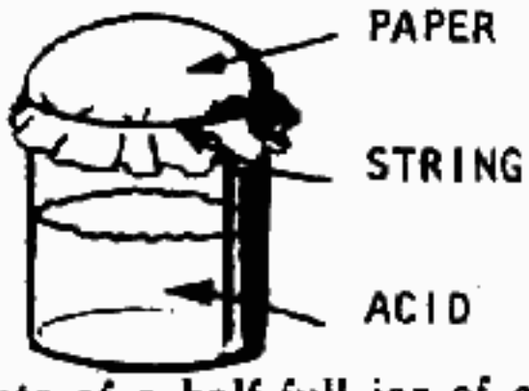
0404. PAPER DIAPHRAGM (SULFURIC ACID)

a. Description.



This device consists of a half-full jar of concentrated sulfuric acid, and a paper diaphragm. The paper diaphragm is a piece of paper tied securely over the mouth of the jar. When the jar is placed on its side, the acid soaks through or corrodes the paper. The acid then contacts the igniter material and causes it to burts into flames. This delay can be used for initiating the following igniters listed in chapter 3: Sugar-Chlorate (0201), Fire Fudge (0202), Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), Match Head (0205), Silver Nitrate—Magnesium Powder (0208).

b. Material and Equipment

Wide-mouthed jar.
Sulfuric acid (concentrated).
Paper.
String.

c. Preparation. Remove the cap from a wide-mouthed jar. Fill about half-full with concentrated sulfuric acid. Tie the paper securely over the mouth of the jar.

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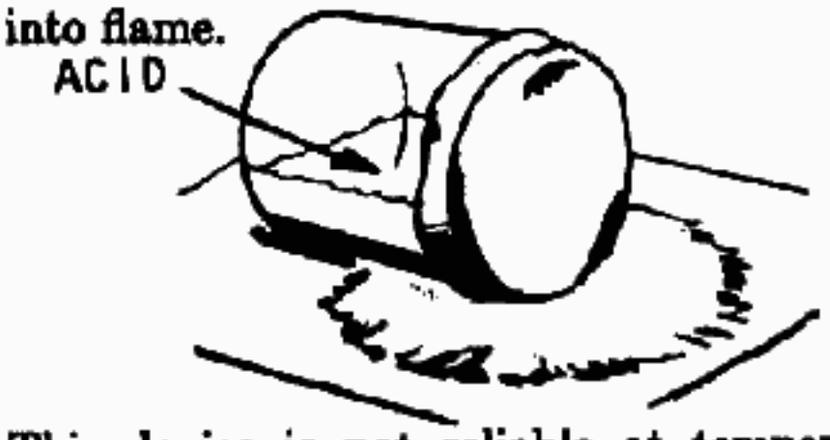
d. Application.

(1) Make a pile of dry flammable material such as rags, papers, empty boxes, or cartons. Spread out a piece of absorbent paper on this material. Spread igniter material on the absorbent paper and place the jar (on its side) on top of the igniter material. Make certain the jar does not leak. When the acid soaks through or corrodes the paper, it will contact the igniter material and cause it to burst into flame.



(2) This device is not reliable at temperatures below 40° F. The time delay depends on the thickness of the paper. A similar device should be tested to determine the delay provided by various thicknesses of paper. It should be tested at the temperature at which it will be used, to be sure of positive ignition. Ignition should occur in about 2 minutes at 68° F. when using writing paper. Higher ambient temperatures shorten delay times, and lower temperatures lengthen delay times.

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0405. PAPER DIAPHRAGM (GLYCERIN)

a. Description.

(1) This device consists of potassium permanganate crystals wrapped in layers of absorbent paper. Glycerin is brought into contact with the wrapped potassium permanganate crystals by slowly soaking through the paper. This wets the wrapped crystals causing combustion. This delay can be used for directly initiating all igniters listed in chapter 3 except White Phosphorus (0209). The igniting ability of this delay is increased when magnesium or aluminum particles are mixed with the potassium permanganate crystals.

(2) The following incendiaries (ch 4) can be directly ignited using this delay: Napalm (0301), Gelled Gasoline (exotic thickeners) (0302), Gelled Gasoline (Improvised thickeners) (0303), Paraffin-Sawdust (0304), and Incendiary Brick (0309). Other combustible dry materials such as paper, rags, straw, and excelsior can also be directly initiated. This delay is not recommended for use in tempertures below 50° F.

b. Material and Equipment.

Absorbent paper (toilet paper, paper, toweling, newspaper).
Glycerin (commercial grade).
Magnesium or aluminum particles (consistency of granulated sugar).
Rubber bands or string.
Small shallow dish.
Potassium permanganate (consistency of coarse ground coffee).
Small bottle (approximately 1½ fluid ounces).
Spoon (perferably nonmetallic).

c. Preparation.

(1) Fill the small bottle with glycerin.
(2) Wrap a quantity of potassium permanganate crystals (a mixture of 85 parts potassium permanganate and 15 parts magnesium or aluminum particles can be substituted to produce a hotter flame) in absorbent paper. Make certain that none of the crystals fall out.
(3) The bottle and package may be carried by the person without hazard to himself, and will be available for use when needed.

d. Application.

(1) To use this delay, pour the glycerin into a small shallow dish or pan. Pile incendiary material around the dish so that when the glycerin ignites it will ignite the incendiary material. Place the paper container of potassium permanganate crystals into the pan of glycerin. When the glycerin soaks through the paper and contacts the potassium permanganate, ignition occurs within a few seconds.

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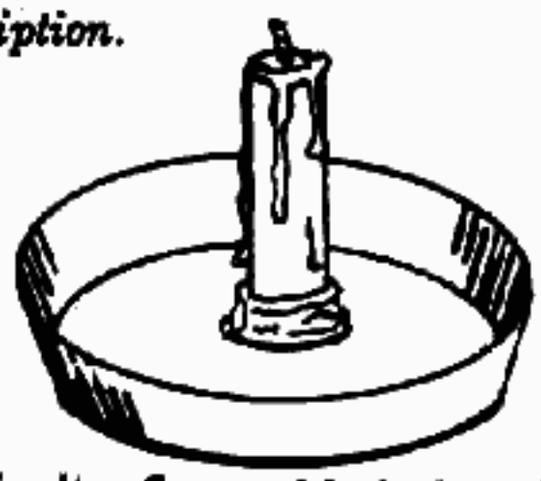
(2) By using various kinds of paper, different delay times can be obtained. Using more layers of paper for wrapping will increase the delay time. Using this delay at higher temperatures will also decrease the delay time. Delay times from one minute to approximately one hour are possible, depending on the conditions.
(3) The delay time should be checked under conditions which are similar to those expected at the target.

0406. CANDLE

a. Description.



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This delay ignites flammable fuels of low volatility such as fuel oil and kerosene. A lighted candle properly inserted in a small container of flammable liquid of low volatility causes ignition of the flammable liquid when the flame burns down to the liquid level. The flame from the burning liquid is used to ignite incendiary material such as paper, straw, rags, and wooden structures. The delay time is reasonably accurate, and may be easily calibrated by determining the burning rate of the candle. No special skills are required to use this delay. Shielding is required for the candle when used in an area of strong winds or drafts. This delay is *not* recommended for use with *highly volatile liquids* because premature ignition may take place. This device is useful where a delay of one hour or longer is desired. The candle delay works well in cold or hot weather, and has the advantage of being consumed in the resulting fire, thus reducing evidence of arson.

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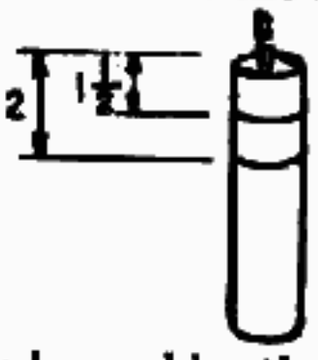
b. Material and Equipment.

Candle.
Bowl.
Perforated can or carton.
Fuel oil or kerosene.
Matches.
Small piece of cloth.

c. Preparation.

(1) Make two marks on the side of the candle, 1½ inches and 2 inches from the top. Light the candle and record the times at which the wax melts at the marks on the side.



(2) The distance burned by the candle divided by the elapsed time determines the burning rate of the candle.

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d. Application.

(1) Using a lighted candle of desired length, drip hot wax in the center of the bowl. Melt the base of the candle with a lighted match.

Firmly press the softened base of the candle into the hot wax in the center of the bowl. Be sure the candle will stand up securely without toppling over. Extinguish the candle. Wrap a small piece of cloth around the candle and slide it down to the bottom of the bowl. Place a quantity of fuel oil or kerosene in the bowl. Be sure that the level of the fluid reaches the cloth, so it will act as a wick. Pile the incendiary material around the bowl where it can catch fire after the fuel oil or kerosene ignites.

(2) If this delay must be set in a windy or drafty location, place a shield over it. Notch or punch holes in a metal can or cardboard carton at the bottom and sides for ventilation, and place this cover over the delay.

0407. OVERFLOW

a. Description.

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This item provides a time delay in starting a fire. It consists of two tin cans, with tops removed, and uses either water or glycerin to activate the igniter material. A hole is punched in the closed end of one can. This can is placed on top of the other can which is partially filled with the liquid. The top can is completely filled with the liquid. When the bottom can fills and overflows, the overflowed liquid will react with the igniter material placed around the bottom can. This device is used for igniting the following water actuated igniters listed in chapter 3: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), and Silver Nitrate—Magnesium Powder (0208). Glycerin is used as the initiating liquid to ignite Potassium Permanganate glycerin (0206).

b. Material and Equipment.

Two tin cans.
Nail or punch.
Hammer.
Water or glycerin.
Can opener.

c. Preparation.

(1) Remove the tops from two cans.
(2) Punch or drill a small hole in the closed end of one of the cans.
(3) Partially fill the other can with either water or glycerin.
(4) Place the can with the hole in the bottom on top of the can partially filled with igniting fluid. Insert a twig or small stick between the two cans to allow the liquid to overflow from the bottom can.
(5) Fill the upper can with the same igniting fluid as that previously placed in the bottom can

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and determine the time required for the fluid to overflow from the bottom can. If two cans of the same size are used, either one may be used for the top. If different size cans are used, place the larger can on top. The delay is variable and adjustable depending on the sizes of the cans, the quantity of liquid used, or the diameter of the hole in the top can.

d. Application.

(1) Always test the glycerin delay at the temperature at which it will be used. Glycerin flows slowly when cold. Do not use water in this delay near or below its freezing point, 32° F.
(2) Place the delay in the target area and fill both upper and lower cans to the desired level with the appropriate liquid.
(3) Pile igniter material around the bottom of the overflow can so the activating liquid can easily make contact with the igniter material as it flows down the side of the can.

0408. TIPPING DELAY—FILLED TUBE

a. Description.

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(1) This delay is composed of a hollow metal rod or bamboo filled with wet beans, rice or peas. The tube is inverted and placed in the center of a ring of igniter material and a small vial of water or acid is tied to the tube. When the wet beans expand, they lift and topple the tube, thereby spilling the acid or water onto the igniter causing combustion.
(2) This tipping delay may be used with a variety of igniters. They are easily prepared, and give fairly accurate delay times. This delay should not be used at temperatures near or

below 32° F. when water is used as the initiator due to freezing. The following water actuated igniters listed in chapter 3 can be used with this mechanism: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204) and Silver Nitrate—Magnesium Powder (0208). The delay may be used with concentrated sulfuric acid to initiate the above igniters and the following acid activated igniters: Sugar-Chlorate (0201), Fire Fudge (0202), and Match Head (0205). This delay may be used with the Glycerin—Potassium Permanganate Igniter (0206).

b. Material and Equipment.

Metal tube, pipe or piece of bamboo closed at one end, 4 to 6 inches long and 1 inch inside diameter, or glass test tube of similar dimensions.

Small glass vial or bottle with open mouth of 1 fluid ounce capacity.

String or rubber bands.

Rice, peas, or beans.

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Water.

Concentrated sulfuric acid.

c. Preparation. The pipe or tube may be made of any material. It must be closed at one end and flat at the other in order to stand vertically. A large glass test tube is ideal for this purpose.

(1) Using some string or rubber bands, attach the small vial to the larger tube. Attach the vial near the top with the open end of the vial pointing up and the open end of the tube down.

(2) This assembly should stand up without toppling over. If it appears unsteady, move the vial downward slightly. A final adjustment may be required when the delay is filled with the required materials.

d. Application.

(1) Rice will usually give delays of about ten to twenty minutes. Peas and beans will usually give delay times up to 4 or 5 hours. Whichever is used it must be first tested to determine the delay time for the tube that will be used.

(2) To use this device, tightly pack the piece of pipe or bamboo with rice, peas or beans

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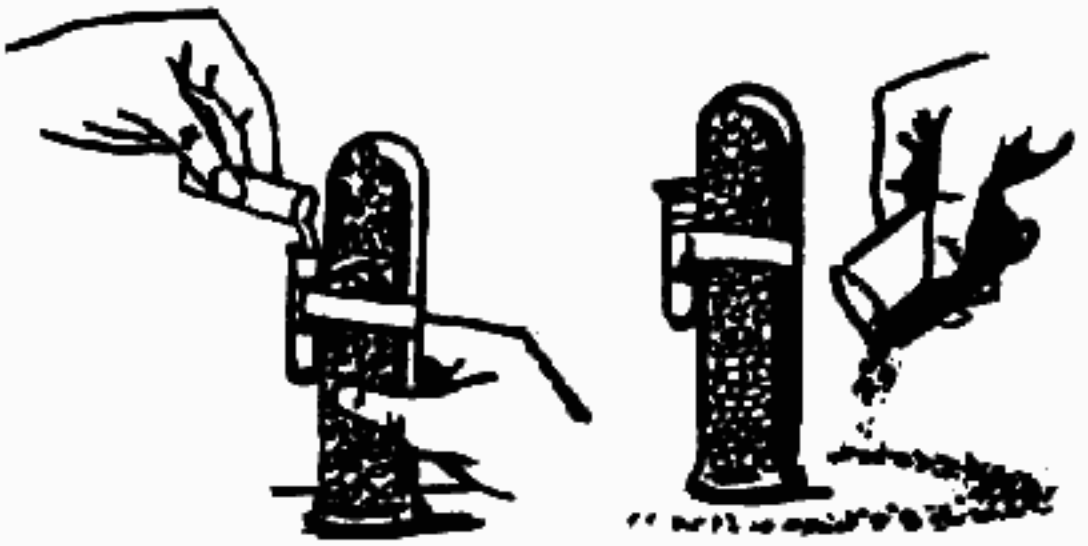
depending on what delay time is required. Add enough water to completely moisten the beans and quickly pour off the excess water. Place the pipe open end down, and immediately fill the small vial with water or concentrated sulfuric acid, depending on which igniter is being used.



(3) Place a quantity of the igniter mixture in a ring around the delay assembly. Make the ring of such diameter that when the tube falls over, the acid or water from the vial will spill onto the igniter mixture.

(4) Place incendiary material where the flame from the igniter will start it burning.

(5) Another way in which the tipping delay can be used is to fill the small vial with glycerin instead of water or acid and then spread potassium permanganate crystals in a ring around the delay. When the glycerin is spilled onto the crystals, combustion will occur and ignite the incendiary material. The glycerin igniter will not work in temperatures below 50° F.

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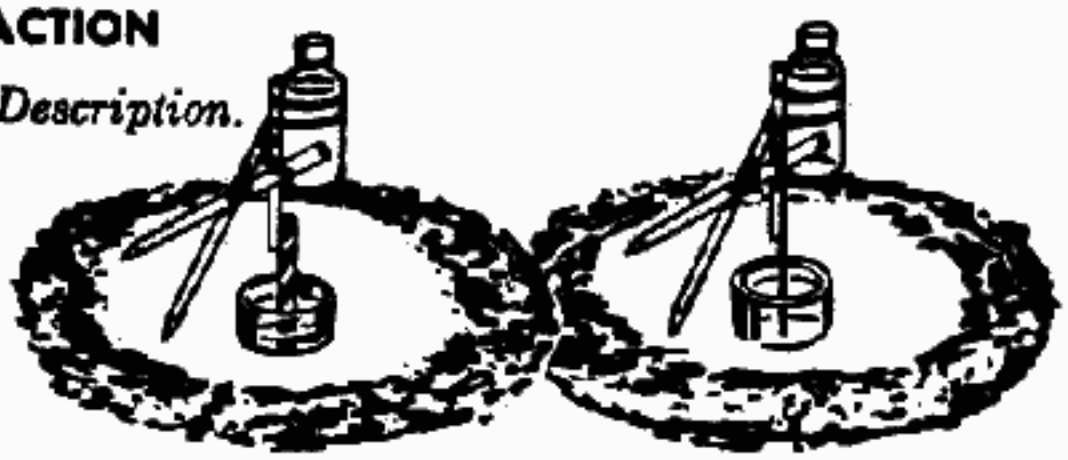
(6) It is recommended that this device be tested at the same temperature at which it is to be used.

0409. TIPPING DELAY—CORROSIVE OR DISSOLVING ACTION

a. Description.



(1) This device consists of a vial of initiating liquid supported by a tripod. One of the legs which supports the vial of liquid is dissolved by a fluid. The center of gravity of the structure changes and the structure topples

over. The contents of the vial spill onto an appropriate igniter mixture and combustion occurs.

(2) This corrosive or dissolving tipping delay may be used with a variety of igniters. However, it should not be used at temperatures near or below 32° F. when water is used as the initiator due to freezing of the water.

(3) The following water actuated igniters listed in chapter 3 can be used with this mechanism:

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Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204) and Silver Nitrate—Magnesium Powder (0208). The delay may be used with concentrated sulfuric acid to initiate the above igniters and the following acid activated igniters: Sugar-Chlorate (0201), Fire Fudge (0202), and Match Head (0205). This delay may be used with the Glycerin—Potassium Permanganate Igniter (0206)'

b. Material and Equipment.

Three wooden sticks or wooden pencils (approximately 6 inches long by ¼ inch diameter).

Glass vial (1 fluid ounce capacity).

String, tape or rubber bands.

Any one of the igniter mixtures mentioned above.

One of the following combination of items:

(1) Long sticks of hard candy and water.

(2) Lengths of bare copper wire and concentrated nitric acid.

(3) Iron nails or wire approximately 1/32 inch diameter by 4 inches long and concentrated hydrochloric acid.

(4) Iron nails or wire and saturated cupric chloride solution.

2 glass containers with glass stoppers for carrying acid.

Shallow glass or porcelain bowl such as soup bowl or ink bottle.

c. Preparation.

(1) Make a tripod out of three sticks, taping them together at the top. Two legs should be the same length; the third should be about 2—3 inches shorter.

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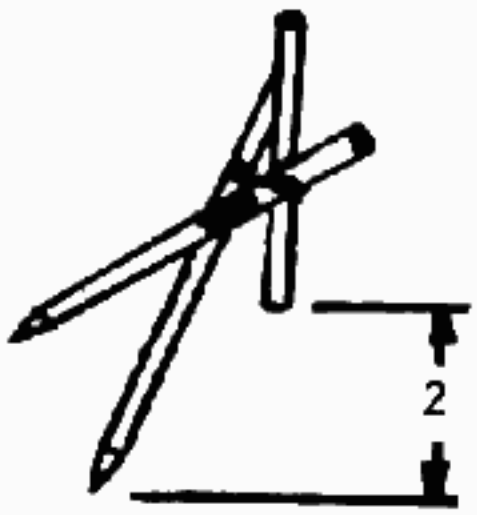
(2) Tape to the short leg, either a stick of hard candy, piece of heavy bare copper wire, steel nail, or steel wire, adjusting the length so that the wire leg stands almost vertically.

(3) The finished tripod should have a distance of about 4—5 inches between any two legs.

(4) To the top of the tripod, on the short leg,



firmly tape or tie the small 1-fluide ounce capacity vial, open end up. Make certain that the tripod still stands upright after attaching the vial. The distance between legs may have to be varied to keep the tripod barely standing upright.

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d. Application.

(1) To use the delay device, insert the leg of the tripod which has the candy, wire, or nails into a glass or porcelain bowl. Fill the vial at the top of the tripod with either water, concentrated sulfuric acid, or glycerin, depending on which igniter is being used. Spread a quantity of the proper igniter material in a ring around the tripod, placing it where the spilled initiating liquid is certain to contact it. Fill the glass or porcelain bowl with the prescribed liquid for dissolving the leg of the tripod in the bowl. For hard candy the liquid is water; for copper wire the liquid is concentrated nitric acid; for steel nails the liquid may be either concentrated hydrochloric acid, or a saturated solution of cupric chloride.

(2) No definite delay times can be established for these delays because of factors such as temperature, solution concentration, and imperfections in the leg of the tripod. Prior to use, test the device under conditions expected

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at the target. The following table should be used merely as a guideline of expected delay times for the various materials.

Delay material	*Delay time*
Hard candy plus water	5—10 minutes
Copper wire plus concentrated nitric acid	2—5 minutes
Copper wire plus nitric acid diluted with an	45—60 minutes

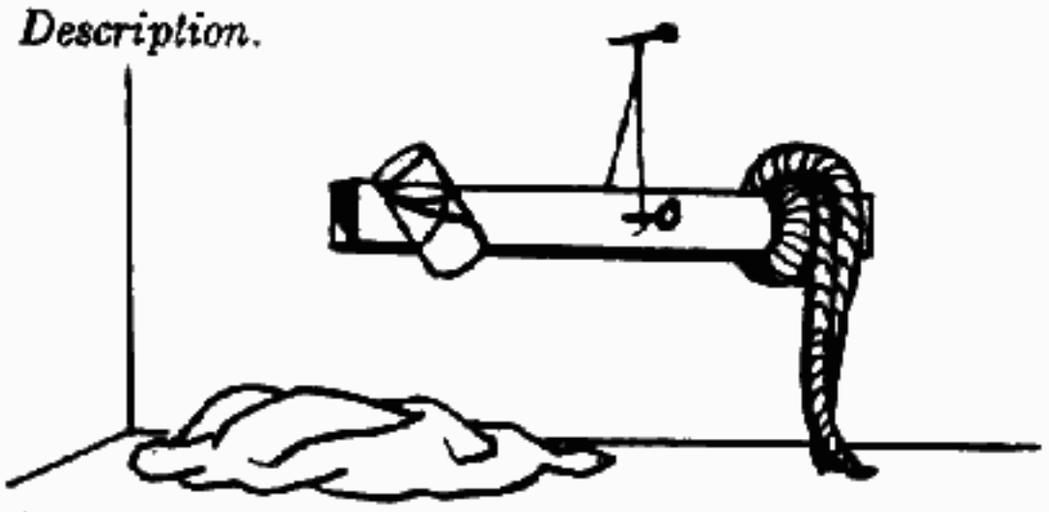
equal volume of water.

Steel wire or nails plus concentrated hydrochloric acid.	24 hours to 7 days
Steel wire or nails plus cupric chloride solution.	10 minutes to 5—6 hours.

(3) The delay time will vary greatly with only moderate changes in temperature. Do not use this type of delay mechanism where accurate delay times are required.

0410. BALANCING STICK

a. Description.



(1) This delay device consists of a piece of wood or stick, a small vial, a nail, a piece of string, and a long strip of cloth. A hole is drilled through the middle of the stick. The vial is

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fastened to one end, and the strip of cloth to the other. The length of the cloth is adjusted so that the rod just balances on a nail passing through the hole when the vial is ¾ full. The cloth is wetted with solvent to make it heavy and the vial is filled with initiating liquid to maintain balance. As the solvent evaporates, the end of the stick which supports the vial of initiating liquid becomes heavier than the end supporting the cloth. The unbalanced stick rotates about the nail until the initiating liquid spills onto the igniter mixture and combustion occurs. Fire then spreads to and ignites incendiary material.

(2) This device may be used with a variety of igniters. However, it should not be used at temperatures near or below 32° F. when water is used as the initiator due to freezing of the water. The following water actuated igniters listed in chapter 3 can be used with this mechanism: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204) and Silver Nitrate—Magnesium Powder (0208). The device may be used with concentrated sulfuric acid to initiate the above igniters and the following acid activated igniters: Sugar-Chlorate (0201), Fire Fudge (0202), and Match Head (0205). It may also be used with the Glycerin—Potassium Permanganate Igniter (0206).

b. Material and Equipment.

Piece of wood (⅞ by ⅞ by 16 inches).

2 Nails.

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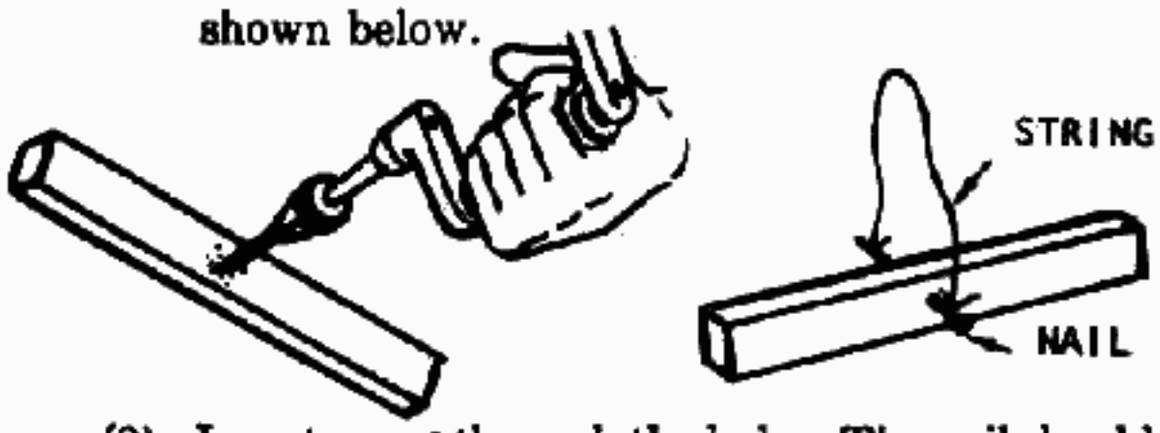
String.

Strip of cloth.

2 glass vials (1 fluid ounce) with stoppers.

c. Preparation.

(1) Drill a hole through the middle of the stick as shown below.



(2) Insert a nail through the hole. The nail should permit the stick to turn freely. Tie a piece of string (4–6 inches in length) to both ends of the nail, forming a loop. It is not important that the stick balance exactly.

(3) To one end of the stick tape a small glass vial. Tilt the vial when attaching it so that when this end of the stick is about 8 inches above the other end, the vial will be vertically upright. On the other end of the stick tie a strip of cloth, rag, or rope. This strip should be heavy enough so that the stick is balanced when the vial is about ¾ full of initiating fluid.

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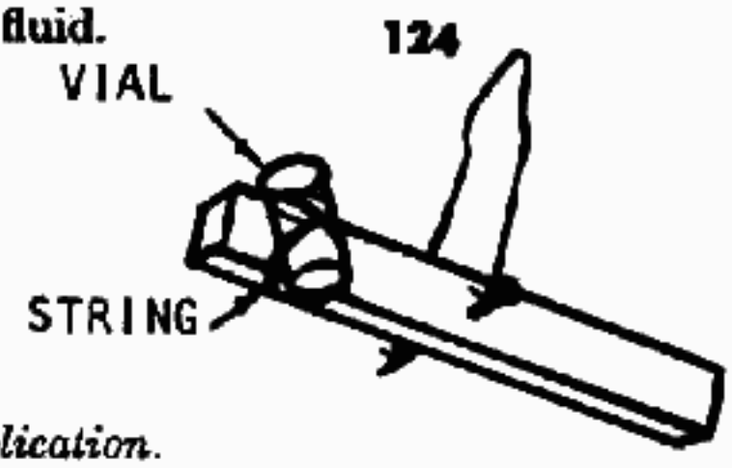

d. Application.

(1) To use this delay, drive a nail (approximately 4 inches long) into a wall or wooden box about 8 inches above the floor, leaving at least 2 inches of the nail projecting. Place the loop of string on the nail near the head of the nail. The stick should not touch the box or wall, but must swing freely. The rag should touch the floor. Pour enough solvent on the rag to soak it thoroughly (approximately 1 fluid ounce). Working quickly, fill the vial with initiating liquid and balance the rod by shifting the cloth. Spread a quantity of appropriate igniter mixture on the floor where the initiating liquid will spill when the solvent

on the cloth evaporates. In a few minutes the solvent will evaporate, causing the stick to become unbalanced. The vial will tilt with the stick and, the liquid in the vial will pour out and initiate the igniter mixture.

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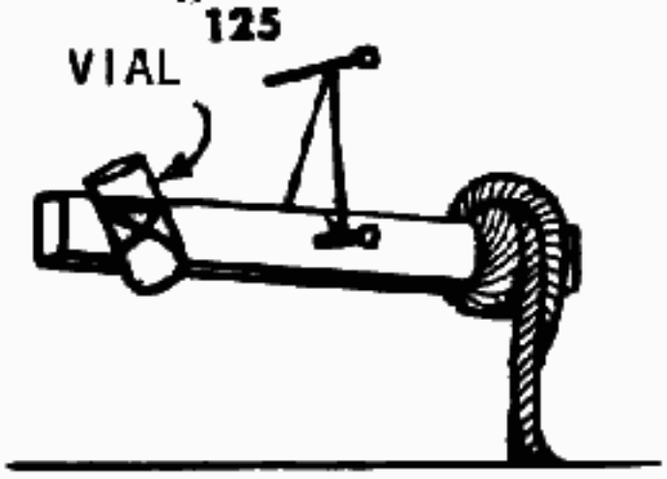
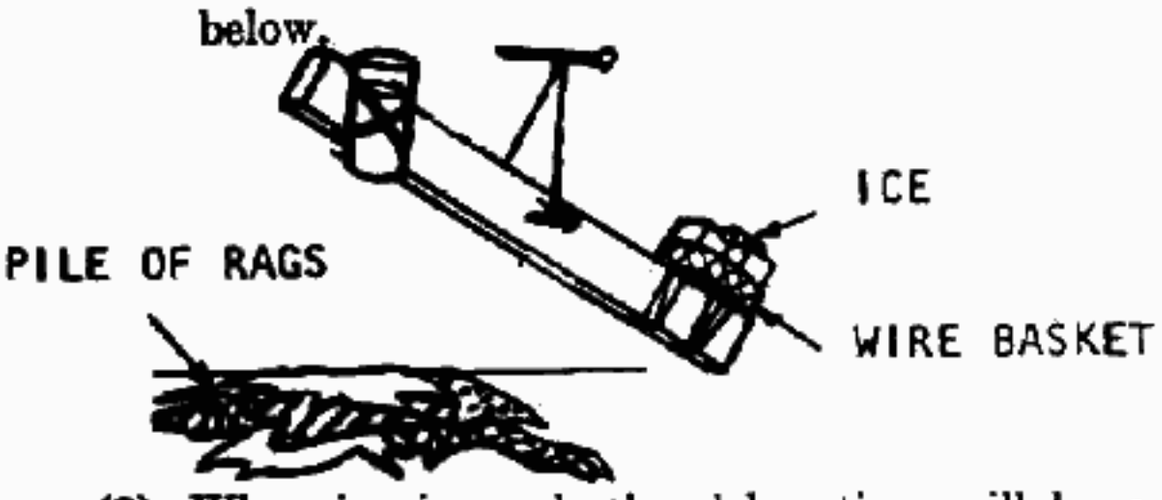


(2) Where no solvent is available or where the odor of solvent may make the device easy to detect, do not use cloth soaked with solvent. Use a wire basket containing ice as shown below.



(3) When ice is used, the delay time will be a matter of minutes, depending on the ambient temperature. Ice cannot be used at temperatures near 32° F. Be sure that the drippings from the melting ice does not wet the igniter or interfere with initial combustion of flammable material.

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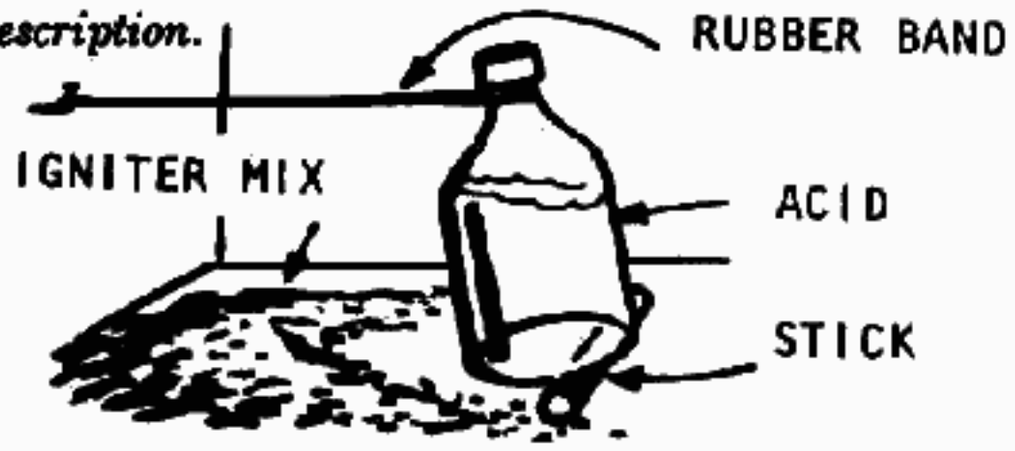
0411. STRETCHED RUBBER BAND

a. Description.



This item utilizes a rubber band, which has been soaked in gasoline or carbon disulfide until it has considerably expanded. After removal of the rubber band from the solvent, the rubber band is attached to a wall and to a bottle containing igniter fluid. As the rubber band contracts due to solvent evaporation, the bottle is tipped and initiator liquid comes in contact with an appropriate igniter material. This stretched rubber band delay may be used with a variety of igniters. However, it should not be used at temperatures near or below 32° F. when water is used as the initiator because the water freezes. The following water actuated igniters listed in chapter 3 can be used with this mechanism: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), and Silver Nitrate—Magnesium Powder (0208). The delay may be used with concentrated sulfuric acid to initiate the above igniters and the following acid activated igniters: Sugar-Chlorate (0201), Fire Fudge (0202), and Match Head (0205). This delay may be used with Glycerin—Potassium Permanganate Igniter (0206).

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b. Material and Equipment.

Bottle or jar (1 to 2 fluid ounce capacity).
Rubber bands.
Gasoline or carbon disulfide.
Air tight container for carrying the gasoline or carbon disulfide.
Nails.
Igniter.

c. Preparation.

(1) Fill a bottle (1 to 2 fluid ounce capacity) with water, acid, or glycerin, depending on which igniter is to be used.

(2) Soak the rubber bands in gasoline or carbon disulfide for about one hour. Do not soak too long or they will become excessively weakened.

d. Application.

(1) At the place where the delay is to be used, drive a large headed nail into the wall, leaving about 2 to 2½ inches exposed. Loop the rubber bands over the head of the nail. Place the bottle two bottle heights away from the nail. Quickly loop the free end of the rubber bands over the neck of the bottle. Move the bottle back and forth until there is just enough tension in the rubber bands to hold the bottle without it toppling when a pencil or twig is placed under the far end. The stick under the end of the bottle is used as a tilt device to make sure that the bottle topples over when the rubber band contracts.

(2) Place some incendiary material close to the bottle. Sprinkle a quantity of igniter mixture about the area in which the liquid will be spilled. As the solvent evaporates, the rubber

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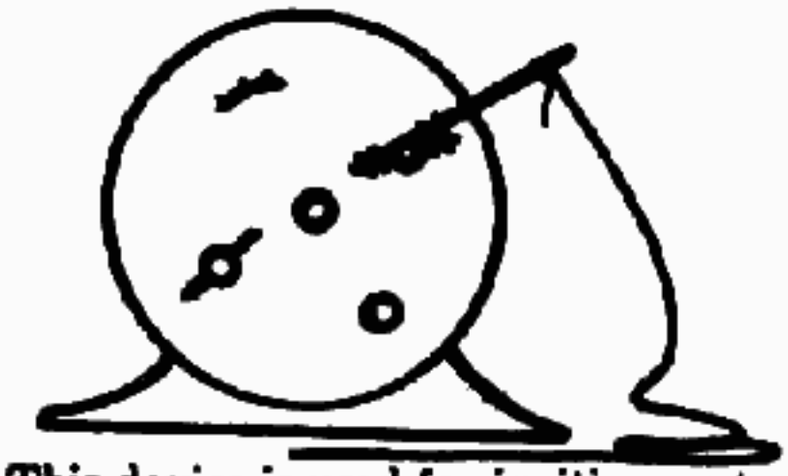
bands will shrink, tip the bottle, spill the liquid, and initiate the igniter material.

Note. Always set up the bottle before spreading the igniter mixture.

0412. ALARM CLOCK

a. Description.



(1) This device is used for igniting materials after a definite delay time. The device employs a manually-wound alarm clock, with the alarm bell removed, as the timing mechanism. A piece of string is fastened to the key used to wind the alarm. The other end of the string is fastened to a bottle of appropriate initiating liquid. When the modified alarm mechanism is tripped, the winding key will reel in the string and overturn the bottle of initiating liquid and start a fire.

(2) This alarm clock delay may be used with a variety of igniters. However, it should not be used at temperatures near or below 32° F. when water is used as the initiator because the water freezes. The following water actuated

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igniters listed in chapter 3 can be used with this mechanism: Sugar—Sodium Peroxide (0203), Aluminum Powder—Sodium Peroxide (0204), and Silver Nitrate—Magnesium Powder (0208). The delay may be used with concentrated sulfuric acid to initiate the above igniters and the following acid activated igniters: Sugar-Chlorate (0201), Fire Fudge (0202), and Match Head (0205). This delay may be used with Glycerin—Potassium Permanganate (0206).

(3) This device will produce fairly accurate delay times between one and eleven hours.

Caution: **The ticking sound of the clock may reveal the presence of the device.**

b. Material and Equipment.

Alarm clock, manually wound (without bell, if possible).
Bottle.
String.
Initiator liquid.
Cloth or absorbent paper.

c. Preparation.

(1) Remove the bell or striker from the clock.
(2) Fully wind time and alarm springs.
(3) Set desired time on alarm.
(4) Tie the string to the alarm key so that it will be pulled when the alarm mechanism is tripped. If necessary, tie a twig or stick to the alarm key to obtain a longer level.

d. Application.

(1) Tie the string to the alarm key or stick. Set the clock in place and anchor it if necessary. Muffle the clock with rags, making sure that

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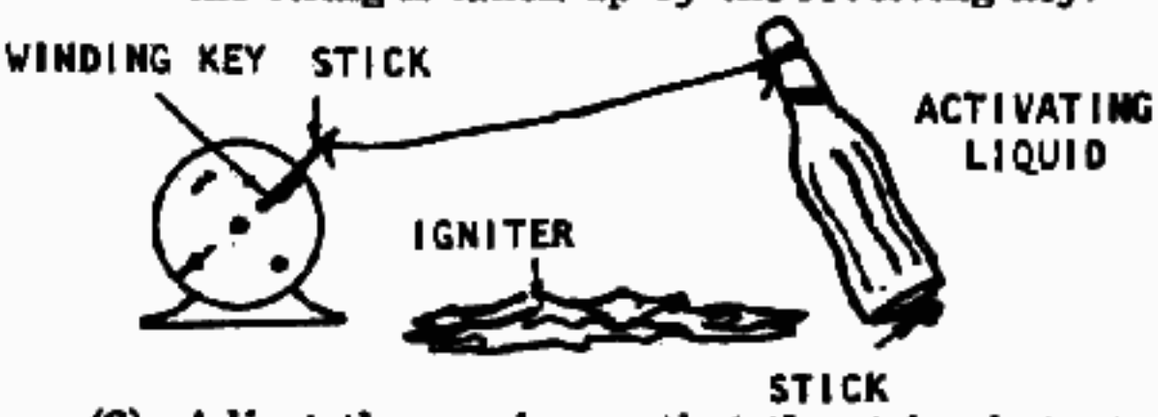
the rags do not interfere with the reeling action of the alarm mechanism. Tie the free end of the string to the bottle of activating liquid. The bottle should be tilted in the direction of the fall by a pencil or twig. When this device is placed on a smooth surface, the clock should be taped, tied, or weighted down to prevent it from sliding when the tension in the string is taken up by the revolving key.



(2) Adjust the spacing so that the string is taut. Place a cloth or an absorbent paper towel where the contents of the bottle will be spilled. Place a quantity of igniter mixture on the cloth or paper towel. Partially overlap the igniter mixture with a flammable material so as to assist combustion.

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CHAPTER 6

SPONTANEOUS COMBUSTION

0501. SPONTANEOUS COMBUSTION

a. Description.

(1) Spontaneous combustion is the outbreak of fire in combustible material that occurs without application of direct flame or spark. A combustible material such as cotton waste, sawdust, or cotton batting is impregnated with a mixture of a vegetable oil and specific drying oils known as driers. This impregnated combustible material is placed in a container which provides confinement around the sides and bottom. Heat produced by the chemical action of the driers in the oil is transferred to the confined combustible material with resultant outbreak of fire. Prepared igniter materials such as Fire Fudge (0202) or initiator material such as Fuse Cord (0101) can

be used with the impregnated combustible material to increase reliability and decrease ignition delay time.

(2) The chemical reaction that supplies heat in the spontaneous combustion device becomes faster as the surrounding temperature rises. Conversely, as the temperature drops ignition delay time increases. In addition, ignition delay time varies somewhat with type of

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vegetable oil, type of drier, type of combustible material, confinement, density of the oil impregnated combustible material, and ventilation. Devices planned for use should be tried in advance to establish delay time.

(3) These devices operate with a natural delay caused by the chemical reaction time of the drying process in the oil. The user places the device and is away from the scene when the fire starts. Spontaneous combustion devices have the added advantage of using items seen daily around shop, plant, or office. Containers for confining the impregnated combustible material can be small waste paper baskets, packing boxes, ice cream containers, paper bags and other items common to a particular operation. Combustible materials such as cotton waste, cotton batting, or sawdust are also common in many manufacturing plants. For these reasons, spontaneous combustion devices are useful and clever sabotage items.

(4) It is recommended that these devices be covertly used to ignite readily flammable material such as rags, dry paper, dry hay, wooden and cardboard boxes, wooden structures, and other similar targets.

b. Material and Equipment.

Ingredient	*Used for*	*Common source*
Vegetable Oils		
Boiled linseed oil	Paint manufacture	Hardware stores
Raw linseed oil	Paint manufacture	Hardware stores
Safflower oil	Food	Drug and food stores
Tung oil (China wood).	Paint manufacture	Paint manufacturers

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Ingredient	*Used for*	*Common source*
Driers		
Cobalt (6%)	Paint manufacture	Paint manufacturers
Lead (24%)	Paint manufacture	Paint manufacturers
Manganese (can be substituted for cobalt).		
Lead oxide (can be substituted for lead).		

Ingredient	*Used for*	*Common source*
Combustible Materials		
Cotton waste	Machine shops, maintenance shops.	By-product of textile manufacture.
Cotton batting	Furniture manufacture.	Felt & textile manufacturers.
Sawdust	Water-oil-grease absorbent.	By-product of food working.
Kapok	Life jackets, furniture padding, bedding.	Furniture manufacturers, food products manufacturers.
Miscellaneous Items		
Cardboard or paper container.	General	Commonly available
Stick approximately 1½ inches in diameter.	General	Commonly available
Sharp knife	General	Commonly available
One pint wide-mouth jar.	General	Commonly available
Teaspoon	General	Commonly available
Fire Fudge Igniter (optional).	Igniter	See paragraph 0202
Fuse Cord (optional).	Initiator	See paragraph 0101

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Proportions of Mixture

System	*Vegetable oil*	*Cobalt drier (teaspoon)*	*Lead drier (teaspoon)*	*Combustible material (tightly packed)*
1	Boiled linseed oil, ⅓ pint.	½	2	Cotton waste, 1 pint.
2	Boiled linseed oil, ⅓ pint.	½	2	Cotton batting, 3 pints.
3	Boiled linseed oil, ⅓ pint.	½	2	Sawdust, 1 pint
4	Boiled linseed oil, ⅓ pint.	½	2	Kapok, 1 pint
5	Raw linseed oil, ⅓ pint.	1	4	Kapok, 1 pint
6	Safflower oil, ⅓ pint.	½	2	Cotton waste, 1 pint.
7	Safflower oil, ⅓ pint.	½	2	Cotton batting, 3 pints.
8	Safflower oil, ⅓ pint.	½	2	Sawdust, 1 pint
9	Safflower oil, ⅓ pint.	½	2	Kapok, 1 pint
10	Tung oil, ⅓ pint.	½	2	Cotton waste, 1 pint.
11	Tung oil, ⅓ pint.	½	2	Cotton batting, 3 pints.
12	Tung oil, ⅓ pint.	½	2	Sawdust, 1 pint
13	Tung oil, ⅓ pint.	½	2	Kapok, 1 pint

Note. The above quantities for each system are approximately correct for use in a 1 gallon confinement container. The impregnated combustible material should fill the container to approximately ⅓ to ½ the volume for best results. Different size containers can be used with properly adjusted quantities of impregnated combustible material. At approximately 70° F., delay time to ignition is roughly 1 to 2 hours. With

Fire Fudge or Fuse Cord added to the impregnated combustible material, delay time is reduced to roughly ½ to 1 hour. The exception to this is System 8 where delay time to ignition is about 2 to 3 hours. With Fire Fudge or Fuse Cord added, delay time is shortened to 1 to 2 hours.

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c. Preparation.

(1) *General instructions.*

(*a*) Measure the combustible material by tightly packing it up to the top of the one pint measuring jar. The material should puff out of the measuring jar when firm hand pressure is removed.

(*b*) Transfer the combustible material from the measuring jar to the container in which it is to be confined.

(*c*) Pour the vegetable oil into the one pint measuring jar to one-third jar volume.

(*d*) Using a teaspoon, add the specified quantity of Cobalt Drier to the vegetable oil in the one pint measuring jar. Wipe the spoon dry and add the specified quantity of Lead Drier to the Vegetable Oil—Cobalt Drier mixture.

(*e*) Thoroughly mix the combination of vegetable oil and driers by stirring with the teaspoon for approximately one minute.

Note. Vegetable oil and drier can be mixed and stored in an air-tight container for one week before use. Longer storage is not recommended.

(*f*) Pour the oil mixture from the one pint measuring jar over the combustible material in the container. Saturate the combustible material by kneading, pulling and balling with the hands. This can be accomplished either inside or outside of the container.

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(*g*) Remove saturated combustible material from the container.

(*h*) Cut a hole with a knife, one to two inches in diameter, in the bottom center of the container.

(*i*) Place the container on a flat surface, hold the 1½-inch diameter stick vertically over the hole in the bottom of the container and pack the saturated combustible material

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around the stick compressing it so that it fills ⅓ to ½ of the container volume after hand pressure is removed.

(*j*) Remove the stick. This leaves a ventilation hole through the center of the combustible material. The spontaneous combustion device is now ready for use unless the following optional step is taken.

(*k*) This step is optional. *Either* take a piece of Fire Fudge (0202) about the size of a walnut and crush it into pieces about the size of peas. Sprinkle the pieces of crushed Fire Fudge on top of the combustible

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material. *Or* cut a piece of Fuse Cord (0101) to a length of about four inches. Since safety fuse burns inside the wrapping, it is sliced in half to expose the black powder. (Lacquer coated fuse (nonsafety type) burns completely and may be used without slicing.) Insert one or more pieces of fuse vertically in the combustible materiel near the center vent hole, leaving about one inch extending out of the top surface of the

combustible material.

(2) *Preparation of improvised driers.* If the commercial driers (cobalt and lead) specified under *Material and Equipment* above are not available, the following improvised driers can be made using either flashlight batteries or powdered lead oxide (Pb_3O_4). These improvised driers are used in the same manner as the commercial driers.

(a) *Manganese drier.*

1. Break open three flashlight batteries (size

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D) and collect the pasty material surrounding the central carbon rod.

2. Put this material in a one-pint wide-mouth jar and fill jar with water.

3. Slowly stir contents of jar for approximately two minutes and allow contents to settle. The contents will usually settle in one-half hour.

4. Pour off water standing on top of settled contents.

5. Remove wet contents from jar, spread it on a paper towel and allow to dry.

6. Dry the jar.

7. Pour raw linseed oil into the one-pint measuring jar to one-third jar volume.

8. Combine the measured quantity of raw linseed oil and the dried battery contents from *5* above in a pot and boil for one-half hour.

9. Shut off heat, remove pot from the heat source, and allow the mixture to cool to room temperature.

10. Separate the liquid from the solid material settled on the bottom by carefully pouring the liquid into a storage bottle. Discard the solid material. The liquid is the drier.

11. The manganese drier is ready for use.

12. If manganese dioxide powder is available, flashlight batteries need not be used. Place one heaping teaspoonful of manganese dioxide powder into the raw linseed oil and boil the mixture in a pot for one-half hour. Then follow *9*, *10*, and *11* above.

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(b) *Lead oxide drier.*

1. Pour raw linseed oil into the one-pint measuring jar to one-third jar volume.

2. Combine the measured quantity of raw linseed oil and two heaping teaspoonfuls of lead oxide in a pot and boil gently for one-half hour. The mixture must be stirred constantly to avoid foaming over.

3. Shut off heat, remove pot from the heat source, and allow the mixture to cool to room temperature.

4. Pour the liquid into a storage bottle and cap the bottle.

5. The lead oxide drier is ready for use.

d. Application.

(1) The spontaneous combustion device is placed at the target on a flat surface with one edge propped up to allow ventilation through the impregnated combustible material.

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Since flames normally shoot up from the open top of the container, combustible target material should be positioned from three to five inches directly over the top of the device for satisfactory ignition of the target. *DO NOT COVER OPEN TOP OF CONTAINER.*

(2) Temperature of the environment in which these devices are used affect, the ignition time these devices are used affects the ignition time. The following table gives approximate time to ignition at different temperatures. However, it is recommended that ignition time be determined by advance trial.

Temperature (° F.)	*Time to ignition (hours)*
60–70	1–2
40–60	2–4
30–40	4–10

(3) Spontaneous combustion devices can also be improvised by stuffing impregnated combustible material into a pocket of any one of the following garments: coat, laboratory jacket, pants, or similar items. The combustible material stuffed in the pocket should be below the top of the pocket and should not be packed too tight.

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IMPROVISED INCENDIARIES

General

Good incendiaries can be improvised more easily than explosives and the materials are more easily obtained. On a pound for pound basis, incendiaries can do more damage than explosives against many type targets if properly used. There is a time lag, however, between the start of a fire and the destruction of the target. During this period the fire may be discovered and controlled or put out. An explosive once detonated has done its work.

Incendiaries are cheap and little training is needed for their preparation and use. Used in very carefully excuted operations, the act of sabotage may be concealed in the ashes of an "accidental" fire.

Fires may be started quickly and have reasonable chance of success if the following few simple principles are observed:

1. See that there is plenty of air and fuel to feed the fire.

2. Use an incendiary that supplies a prolonged and persistent heat.

3. Start the fire low in the target structure and let it spread naturally upwards.

4. Use reflecting surfaces, such as corners, boxes, shelves, to concentrate the heat.

5. Use drafts to spread the fire rapidly — near stairways, elevator shafts.

6. Protect the fire from discovery during the first few minutes by good concealment and timing.

In preparing improvised incendiaries observe basic rules of safety. Chemicals that must be powered should be ground separately with clean tools and then mixed in the indicated proportions. Chemicals or mixtures should be kept tightly sealed in jars or cans to protect them from moisture. Damp materials will work poorly if at all.

Sulfuric acid, which is useful for chemical delays and to ignite incendiaries or explosive detonators, can be obtained by concentrating battery acid. This can be done by boiling off the water in the battery acid in a glass or porcelained pan until dense white fumes begin to appear. This operation should be done out of doors and the resulting concentrated acid should be handled carefully.

The paragraphs which follow will describe the preparation of several igniter (or "first fire") incendiary mixes, some basic incendiary mixes, and a thermate metal-destroying incendiary.

The subject of incendiaries has been treated much more exhaustively in other publications. The intent of this handbook is to provide only a few techniques.

Potassium Chlorate and Sugar Igniter

Chlorate-sugar is one of the best of the first fire or igniter mixes. It burns very rapidly, with a yellow-white flame, and generates sufficient heat to ignite all homemade incendiaries mentioned in this handbook.

MATERIALS: Potassium chlorate (preferred) or sodium chlorate, sugar.

PREPARATION:

1. Grind the chlorate separately in a clean, non-sparking (glass or wooden) bowl with a wooden pestle. the resulting granules should approximate those of ordinary table sugar.

2. Mix equal volumes of the granulated chlorate and sugar by placing both on a large sheet of paper and then lifting the corners alternately.

CAUTION: This mixture is extremely spark sensitive and must be handled accordingly.

3. Wrap 4 to 6 tablespoonfuls of the mixture in thin paper so as to form a tight packet. Keep the mixture as dry as possible. If it is to be stored in a damp area before using, the packet may be coated with paraffin wax.

Chlorate-sugar is easily ignited by the flame of a match, the spit of a percussion cap or time fuse, with concentrated sulfuric acid.

If ignited when under confinement it will explode like gunpowder. If it is contained in a waxed packet, therefore, the latter should be punched through in several places before it is used with a basic incendiary and ignited.

Flake Aluminum-Sulfur Igniter

This simple igniter burns extremely hot and will ignite even the metal-destroying thermate, described later on. The mixture itself can be lit by chlorate-sugar.

MATERIALS: Flake aluminum, finely powdered sulfur.

PREPARATION:

1. Mix 4 parts by volume of finely powdered sulfur with 1 part of aluminum powder.

To use, place several spoonfuls of the mixture on the material to be lit and add a spoonful of chlorate-sugar on top. Be sure the safety (time) fuse or other spark-producing delay system is placed so it will act upon the chlorate-sugar mixture first.

Homemade Black Powder Igniter

Black powder may be used for igniting napalm, flammable solvents in open containers, paper, loose rags, straw, excelsior and other tinder type materials. If it is not available already mixed, it can be prepared as follows:

MATERIALS: Potassium (or sodium) nitrate, powdered charcoal. powdered sulfur, powder

PREPARATION:

1. Into a clean, dry jar or can put 7 spoonfuls of potassium or sodium nitrate, 2 spoonfuls of powdered charcoal, and 1 spoonful of powdered sulfur. The ingredients must be at least as fine as granulated sugar. If they must be ground, GRIND EACH SEPATATELY. Never grind the mixed ingredients — they may ignite or explode.

2. Cap the can or jar tightly and shake and tumble it until the ingredients are completely mixed.

The mixture will be effective for months if kept tightly sealed and dry. Sodium nitrate in particular has a tendency to absorb moisture.

To use the gunpowder, pile 2 or 3 spoonfuls on top of any solid incendiary material which is to be ignited. For igniting liquids in open containers, wrap 2 or 3 spoonfuls in a piece of paper and suspend it just above the liquid.

Gunpowder is best ignited by safety fuse. It burns very quickly and with a great deal of heat, so allow sufficient time delay for safe withdrawal from the vicinity.

Match Head Igniter

A good ignition material for incendiaries can be obtained from the heads of safety matches, which are available almost any place. The composition must be removed from the heads of many of them to get a sufficient quantity of igniter material. It will ignite napalm, wax and sawdust, paper, and other flammables.

MATERIALS: Safety matches.

PREPARATION:

Remove the match head composition by scraping with a knife or crushing with pliers. Collect several spoonfuls of it and store in a moisture-tight container.

Put at least 2 spoonfuls on the material to be ignited. To ignite liquids, such as solvents or napalm, wrap several spoonfuls in a piece of

paper and hang this just over the fluid, or place nearby. If fluids dampen the mixture it may not ignite.

Ignition can be by time fuse, fircracker fuse, a spark, or concentrated sulfuric acid.

Time Fuse Fire Starter

Several igniters or first fire mixes can be set off by a spark from time fuse. Others require a stronger flame. Time fuse, plus matches, can be combined to improve this more intense initial flame.

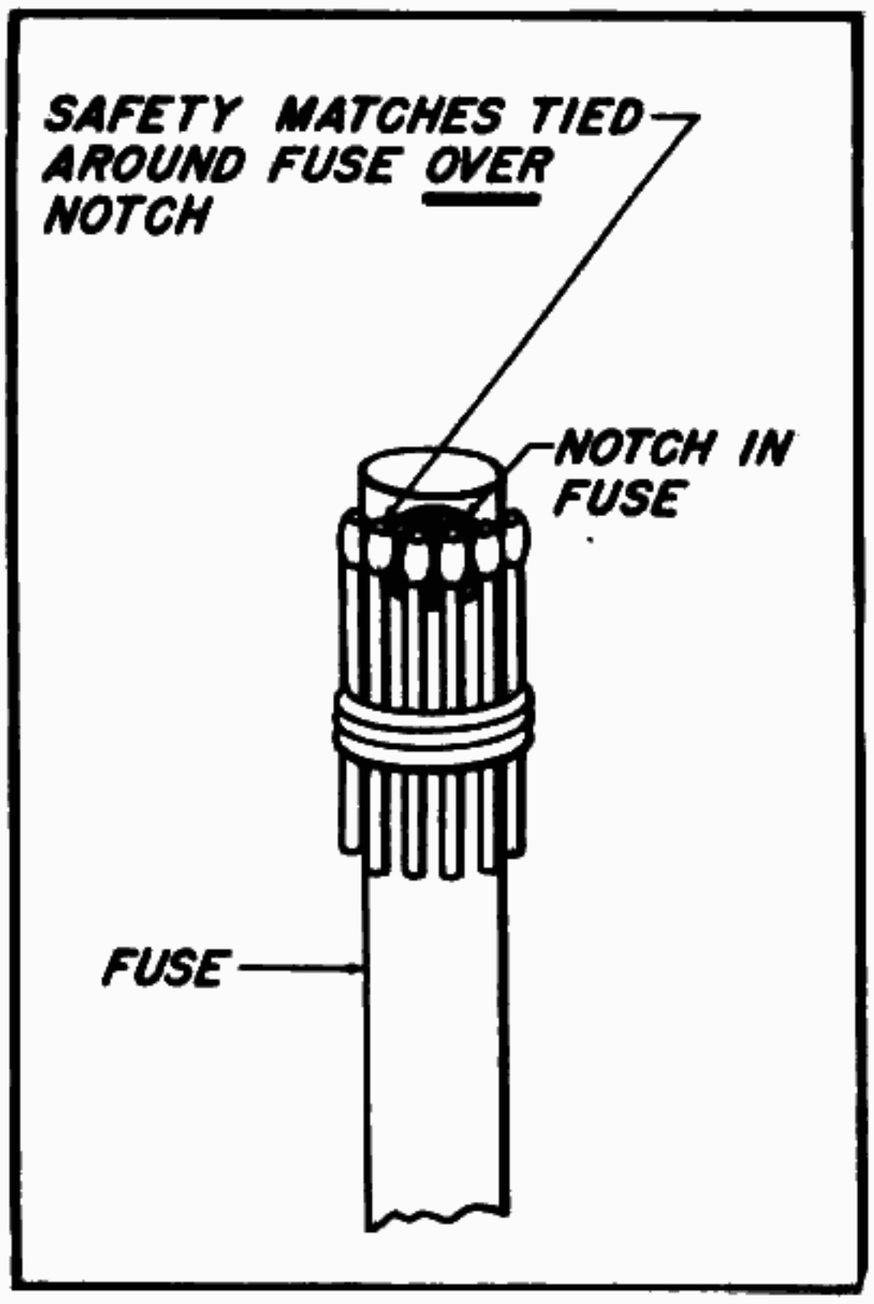
MATERIALS: Time (safety) fuse, safety matches, string or tape.

PREPARATION:

1. About ¼ inch from the end of a piece of time fuse cut a notch with a sharp knife so that the powder train is exposed.

2. Around the fuse at this point tape or tie several matches so that their heads are in contact with each other and at least one match head is directly over the notch. See Figure 59.

When the fuse burns down, a spark from the notch ignites the one match head, which flares and ignites the others. this fire starter can be inserted into an igniter mix or used alone to light crumped paper or excelsior. Another application, nonelectric firing of the 3.5" rocket, is described earlier.



Time Fuse Fire Starter

Homemade Napalm

Napalm is the best incendiary to use against most flammable targets. It will readily ignite paper, straw, flammable solvents, or wooden structures.

MATERIALS: Gasoline or fuel oil, nondetergent soap (bar, flakes, or powder).

PREPARATION:

1. Use about equal parts of soap and oil. If bar soap is used, slice it into small chips. If both gasoline and fuel oil are available, use both in equal parts.

2. Heat the fuel in an open container, preferably one with a handle, out of doors. Try to avoid creating sparks or having a high open flame, but if the fuel should catch on fire extinguish it by placing a board or piece of tin over the container.

3. Gasoline, in particular, will begin to bubble very quickly. When it does, remove from the fire and gradually add the soap, stirring continuously, until the soap is completely dissolved and a thin pasty liquid results. If necessary return the mixture to the fire, but as a safety measure it is best not to stir while the container is on the fire.

4. When the desired consistency is reached allow the mixture to cool.

5. Napalm also can be mixed by a cold method, although it may take hours to thicken. This should be done by alternately adding very small

Molotov Cocktail

amounts of soap chips or powder and gasoline or fuel oil and stirring until the mixture reaches a thin jelly-like consistency. It is best to start with about a cupful of soap, add part of a cup of solvent and stir that until smooth before gradually adding the remaining ingredients. Continuous stirring is not required. In fact, it is advisable just to let the mixture and the mixer rest from time to time and give the soap a chance to dissolve.

Napalm will keep well if stored in a tightly sealed container. It can be ignited with a match or any of the first fire mixtures described previously. The ignition packet should be placed adjacent to or just over the napalm, otherwise the petroleum may soak it and prevent its burning.

When napalm is used on easily ignitible materials (such as loosely piled paper, rags, or hay) it should be spread out so it will start a large area burning at once. Tightly baled paper or rags should be loosened first, because they do not burn well. If used directly against wooden structures or other large articles which are diffcult to ignite, the napalm should be concentrated in sufficient quantity to provide a hot, long lasting blaze. If about a half dozen pieces of charcoal are put into and around the napalm the heat output is considerably increased.

Napalm makes an excellent "Molotov cocktail." Just fill any glass bottle with a small neck with the napalm and cram a twisted strip of cloth into the mouth of the bottle as a stopper. See Figure 60. When ready to use, pull about 4 to 6 inches of the rag stopper out of the bottle. Light the napalm-soaked rag with a match and, when the rag is burning well, throw the bottle at the target. When the bottle breaks napalm spashes over the target and is ignited by the burning rag.

Paraffin-Sawdust Incendiary

Paraffin-sawdust is almost as effective as napalm against combustible targets, but it is slower in starting. It is solid when cool and thus is more easily carried and used than liquid napalm. In addition, it can be stored indefinitely without special care.

MATERIALS: Dry sawdust, paraffin, beeswax, or candle wax.

PREPARATION:

1. Melt the wax, remove the container from the fire and stir in a roughly equal amount of sawdust.

2. Continue to stir the cooling mixture until it becomes almost solid, then remove from the container and let it cool and solidify further.

Lumps of the mixture the size of a fist are easiest to manage. The chunks of incendiary may be carried to the target in a paper bag or other wrapper. Any igniter that will set fire to the paper wrapper will ignite the wax and sawdust.

A similar incendiary can be made by dipping sheets of newspaper into melted wax and allowing them to cool. These papers may then be

crumpled up and used in the same manner as the paraffin-sawdust, although they will not burn as hot and persistently.

Sawdust, Moth Flakes, and Oil Incendiary

This incendiary is very good for use against all kinds of wooden structures, including heavy beams and timbers. It also works well on paper, rags, straw, excelsior, and other tinder type materials. It will start fires in open containers of flammable liquids, piles of coal, coke, or lumber, and on baled rags and paper. It is not effective against metal.

MATERIALS: Dry sawdust, moth flakes (naphthalene), fuel oil (kerosene or diesel oil).

PREPARATION:

1. Place equal parts of sawdust, moth flakes, and oil into a container and stir until the mixture is the consistency of mush.

2. Store it in any container that will retain the oil fumes.

An easy, effective way to use this mixture is to put about a quart of it in a paper bag and place the bag on the target material. The bag can be lit with a match and the mixture will ignite quite readily. It burns as well as napalm. If a longer delay time is required, use one of the igniter mixes described earlier along with time fuse or other delay device. The time fuse alone, however, will not ignite the incendiary mix.

Where very large wood beams are to be burned, an additional amount of the incendiary will be required. Two or three quarts is enough to destroy almost any target against which the technique would be effective.

For the greatest effect on wooden structures, the mixture should be in a pile, never spread out in a thin layer. It should be placed beneath the target material, if possible, so the flames will spread upward. In a packing box or room, a corner is a good place to start the fire.

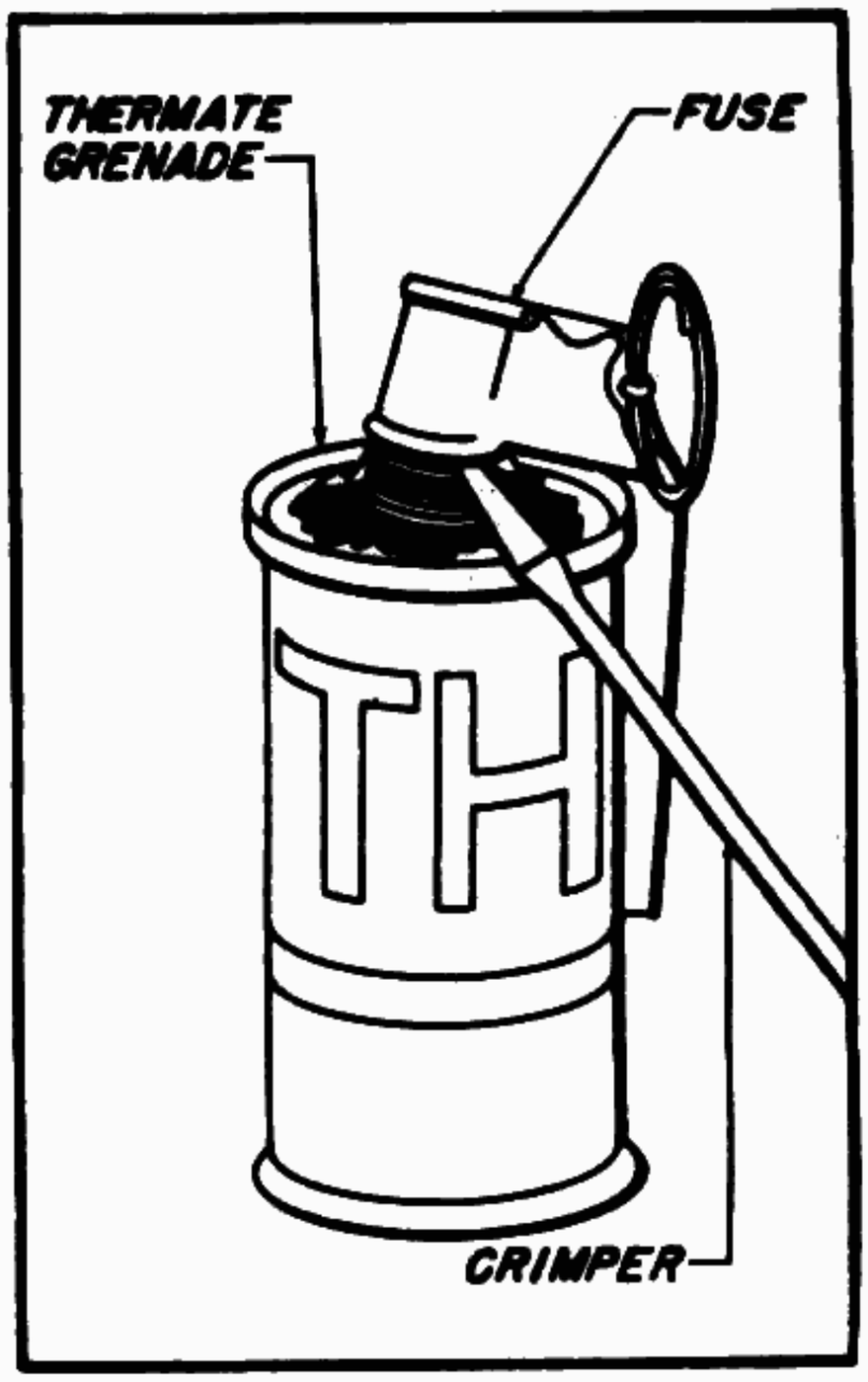
Thermate Incendiary

Thermate is similar to commercial thermit, used in welding, except that it also contains an oxidizer, making it easier to ignite. Thermate will readily burn paper, rags, excelsior, straw, and other tinder type materials. However, its main use in sabotage operations is against motors, gears, lathes, or other metal targets — to weld moving parts together, warp precision machined surfaces, and so on. Since it burns with a brief, almost explosive action, it is not recommended for burning wooden structures or other materials where persistent heat is required.

A good source of ready-made thermate is the U.S. military AN M-14 Incendiary Grenade. To remove the thermate, first pry out the fuse assembly with crimpers or other nonsparking implement. See Figure 61. The reddish-brown caked substance on top of the contents of the grenade is a first fire mixture and it is spark sensitive. This should be broken up and the grayish powder beneath, which is the thermate, can be poured out.

Thermate also can be made from aluminum or magnesium powder and a chemical oxidizing agent, as described below:

MATERIALS: Aluminum filings, powder or flakes, or magnesium filings or powder, plus any one of the following chemicals: potassium nitrate, sodium nitrate, barium nitrate, potassium dichromate, sodium dichromate, or potassium permanganate. Although aluminum and magnesium are equally effective, thermate made from magnesium is easier to ignite. Flake aluminum, which is the extremely fine variety used in paints, is excellent. In any case, both the metal and chemical



Defusing Thermate Grenade

ingredients should be no coarser than granulated sugar.

PREPARATION:

1. Fill a quart size (or larger) container about 2/3 full of equal parts of the metal powder and the oxidizing agent.

2. Cover with a tight lid, then roll and tumble the container until the contents are completely mixed.

3. If flake aluminum is the metal used, fill the container ⅓ full of the aluminum then add oxidizing agent until the container is ¾ full. Mix as described above.

Thermate in a sealed container can be stored for months. To use, put 1 or 2 pounds of the mixture in a paper bag and place it on the target in such a way that when it burns the red hot molten material will run down and attack the vital parts.

Chlorate-sugar and aluminum-sulfur igniters are best for setting off thermate, particularly if the thermate contains aluminum powder, which is more difficult to ignite.

Thermate also is used in the improvised dust initiator and the external POL charges described later.

Commercial Explosives

I have included here the essentials of the US Army FM 5-250. Take the time to read this, it is like an undergraduate degree in explosive demolitions. This manual describes the characteristics and proper use of every type of explosive in military use today. The sections on specific demolition operations, such as destroying bridges, contain a wealth of information necessary to the White separatist. This Field Manual is reproduced **without** permission.

1. Military Explosives
2. Initiating, Firing and Detonating Systems
3. Calculation and Placement of Charges
4. Bridge Demolition
5. Demolition Safety

FM 5-250

Chapter 1

Military Explosives

Section I. Demolition Materials

1-1. Characteristics. To be suitable for use in military operations, explosives must have certain properties. Military explosives—

- Should be inexpensive to manufacture and capable of being produced from readily available raw materials.

- Must be relatively insensitive to shock or friction, yet be able to positively detonate by easily prepared initiators.

- Must be capable of shattering and must have the potential energy (high energy output per unit volume) adequate for the purpose of demolitions.

- Must be stable enough to retain usefulness for a reasonable time when stored in temperatures between -80 and +165 degrees Fahrenheit.

- Should be composed of high-density materials (weight per unit volume).

- Should be suitable for use underwater or in damp climates.

- Should be minimally toxic when stored, handled, and detonated.

1-2. Selection of Explosives. Select explosives that fit the

particular purpose, based on their relative power. Consider all characteristics when selecting an explosive for a particular demolition project.

Table 1-1 contains significant information regarding many of the explosives described below.

1-3. Domestic Explosives.

a. Ammonium Nitrate. Ammonium nitrate is the least sensitive of the military explosives. It requires a booster charge to successfully initiate detonation. Because of its low sensitivity, ammonium nitrate is a component of many composite explosives (combined with a more sensitive explosive). Ammonium nitrate is not suitable for cutting or breaching charges because it has a low detonating velocity. However, because of its excellent cratering affects and low cost, ammonium nitrate is a component of most cratering and ditching charges. Commercial quarrying operations use ammonium nitrate demolitions extensively. Pack ammonium nitrate in an airtight container because it is extremely hydroscopic (absorbs humidity). Ammonium nitrate or composite explosives containing ammonium nitrate are not suitable for underwater use unless packed in waterproof containers or detonated immediately after placement.

b. Pentaerythrite Tetranitrate (PETN). PETN is a highly sensitive and very powerful military explosive. Its explosive potential is comparable to cyclonite (RDX) and nitroglycerin. Boosters, detonating cord, and some blasting caps contain PETN. It is also used in composite explosives with trinitrotoluene (TNT) or with nitrocellulose. A PETN-

nitrocellulose composite (Ml 18 sheet explosive) is a demolition charge. The PETN explosive is a good underwater-demolition because it is almost insoluble in water.

1-1

Table 1-1. Characteristics of US demolitions explosives

Name	Applications	Detonation Velocity		RE Factor*	Fume Toxicity	Water Resistance
		M/Sec	Ft/Sec			
Black Powder	Time Fuse	400	1,300	0.55	Dangerous	Poor
Ammonium Nitrate	Cratering Charge	2,700	8,900	0.42	Dangerous	Poor
Amatol 80/20	Bursting Charge	4,900	16,000	1.17	Dangerous	Poor
M1 Dynamite	Demolition Charge	6,100	20,000	0.92	Dangerous	Fair
Detonating Cord	Priming	6,100 to 7,300	20,000 to 24,000	—	Slight	Excellent
TNT	Demolition Charge Composition Explosive	6,900	22,600	1.00	Dangerous	Excellent
Tetrytol 75/25	Demolition Charge	7,000	23,000	1.20	Dangerous	Excellent
Tetryl	Booster Charge Composition Explosive	7,100	23,300	1.25	Dangerous	Excellent
Sheet Explosive M118 and M186	Cutting Charge	7,300	24,000	1.14	Dangerous	Excellent
Pentolite 50/50	Booster Charge Bursting Charge	7,450	24,400	—	Dangerous	Excellent
Nitroglycerin	Commercial Dynamite	7,700	25,200	1.50	Dangerous	Good
Bangalore Torpedo, M1A2	Demolition Charge	7,900	25,800	1.17	Dangerous	Excellent
Shaped Charges M2A3, M2A4, and M3A1	Cutting Charge	7,900	25,800	1.17	Dangerous	Excellent
Composition B	Bursting Charge	7,900	25,800	1.35	Dangerous	Excellent
Composition C4 and M112	Cutting Charge Breaching Charge	8,040	26,400	1.34	Slight	Excellent
Composition A3	Booster Charge Bursting Charge	8,100	26,500	—	Dangerous	Good
PETN	Detonating Cord Blasting Caps Demolition Charges	8,300	27,200	1.66	Slight	Excellent
RDX	Blasting Caps Composition Explosives	8,350	27,400	1.60	Dangerous	Excellent

RDX	Composition Explosives	8,350	27,400	1.60	Dangerous	Excellent
*TNT equals 1.00						

c. Cyclotrimethlenetrinitramine (RDX). RDX is also a highly sensitive and very powerful military explosive. It forms the base charge in the M6 electric and M7 nonelectric blasting caps.

When RDX is desensitized, it serves as a subbooster, booster, bursting charge, or demolition charge.

The principal use for RDX is in composite explosives, such as Composition A, B, and C explosives. RDX is available commercially under the name cyclonite.

d. Trinitrotoluene. TNT is the most common military explosive. It maybe in composite form, such as a booster, a bursting, or a demolition charge, or in a noncomposite form. Since TNT is a standard explosive, it is used to rate other military explosives.

e. Tetryl. Tetryl is an effective booster charge in its noncomposite form and a bursting or a demolition charge in composite forms. Tetryl is more sensitive and powerful than TNT. However, RDX- and PETN-based explosives, which have increased power and shattering effects, are replacing tetryl and composite explosives containing tetryl.

f. Nitroglycerin. Nitroglycerin is one of the most powerful high explosives. Its explosive potential is comparable to RDX and PETN. Nitroglycerin is the explosive base for commercial dynamites. Nitroglycerine is highly sensitive and extremely temperature-sensitive. Military explosives do not use

nitroglycerin because of its sensitivity. Do not use commercial dynamites in combat areas.

g. Black Powder. Black powder is the oldest-known explosive and propellant. It is a composite of potassium or sodium nitrate, charcoal, and sulfur. Time fuses, some igniters, and some detonators contain black powder.

h. Amatol. Amatol is a mixture of ammonium nitrate and TNT. It is a substitute for TNT in bursting charges. Some older bangalore torpedoes use 80-20 amatol (80 percent ammonium nitrate and 20 percent TNT). Because amatol contains ammonium nitrate, it is a hydroscopic compound.

Keep any explosives containing amatol in airtight containers. If properly packaged, amatol remains viable for long periods of time, with no change in sensitivity, power, or stability.

i. Composition A3. Composition A3 is a composite explosive containing 91 percent RDX and 9 percent wax. The purpose of the wax is to coat, desensitize, and bind the RDX particles. Composition A3 is the booster charge in some newer shaped charges and bangalore torpedoes. High-explosive plastic (HEP) projectiles may also contain Composition A3 as a main charge.

j. Composition B. Composition B is a composite explosive containing approximately 60 percent RDX, 39 percent TNT, and 1 percent wax. It is more sensitive than TNT. Because of its shattering power and high rate of detonation, Composition B is the main charge in shaped charges.

k. Composition B4. Composition B4 contains 60 percent RDX,

39.5 percent TNT, and 0.5 percent calcium silicate. Composition B4 is the main charge in newer models of bangalore torpedoes and shaped charges.

l. Composition C4 (C4). C4 is a composite explosive containing 91 percent RDX and 9 percent nonexplosive plasticizers. Burster charges are composed of C4. C4 is effective in temperatures between -70 to+ 170 degrees Fahrenheit; however, C4 loses its plasticity in the colder temperatures.

m. Tetrytol. Tetrytol is a composite explosive containing 75 percent tetryl and 25 percent TNT. It is the explosive component in demolition charges. Booster charges require different mixtures oftetryl and TNT. Tetrytol is more powerful than its individual components, is better at shatteringthan TNT, and is less sensitive than tetryl.

n. Pentolite. Pentolite is a mixture of PETN and TNT. Because of its high power and detonating rate, a mixture of 50-50 pentolite (50 percent PETN and 50 percent TNT) makes an effective booster charge in certain models of shaped charges.

o. Dynamites.

(1) Standard Dynamite. Most dynamites, with the notable exception of military dynamite, contain nitroglycerin plus varying combinations of absorbents, oxidizers, antacids, and freezing-point depressants. Dynamites vary greatly in strength and sensitivity depending on, among other factors, the percentage of nitroglycerin they contain. Dynamites are for general blasting and demolitions, including land clearing,

cratering and ditching, and quarrying.

(2) Military Dynamite. Military dynamite is a composite explosive that contains 75 percent RDX, 15 percent TNT, and 10 percent desensitizers and plasticizers. Military dynamite is not as powerful as commercial dynamite. Military dynamite's equivalent strength is 60 percent of commercial dynamiters. Because military dynamite contains no nitroglycerin, it is more stable and safer to store and handle than commercial dynamite.

1-4. Foreign Explosives.

a. Composition. Foreign countries use a variety of explosives, including TNT, picric acid, amatol, and guncotton. Picric acid is similar to TNT, but it also corrodes metals and thus forms extremely sensitive compounds.

WARNING

Do not use picric acid in rusted or corroded metal containers.

Do not handle picric acid. Notify explosive ordnance disposal (EOD) personnel for disposition.

b. Use. You may use the explosives of allied nations and those captured from the enemy to supplement standard supplies. Only expert demolitionists should use such explosives and then only according to instructions and directives of theater commanders. Captured bombs, propellants, and other devices may be used with US military explosives for larger demolition projects, such as pier, bridge, tunnel, and airfield destruction. Most foreign explosive blocks

have cap wells large enough to receive US military blasting caps. Since foreign explosives may differ from US explosives in sensitivity and force, test shots should be made to determine their adequacy before extensive use or mixing with US-type explosives.

Section II. Service Demolition Charges

1-5. Block Demolition Charges. Block demolition charges are prepackaged, high-explosive charges for general demolition operations, such as cutting, breaching, and cratering. They are composed of the high-explosive TNT, tetrytol, Composition-C series, and ammonium nitrate.

Block charges are rectangular inform except for the 40-pound, ammonium-nitrate block demolition charge, military dynamite, and the ¼-pound-TNT block demolition charge, which are all cylindrical in form. The various block charges available are described in the text that follows.

1-6. TNT Block Demolition Charge.

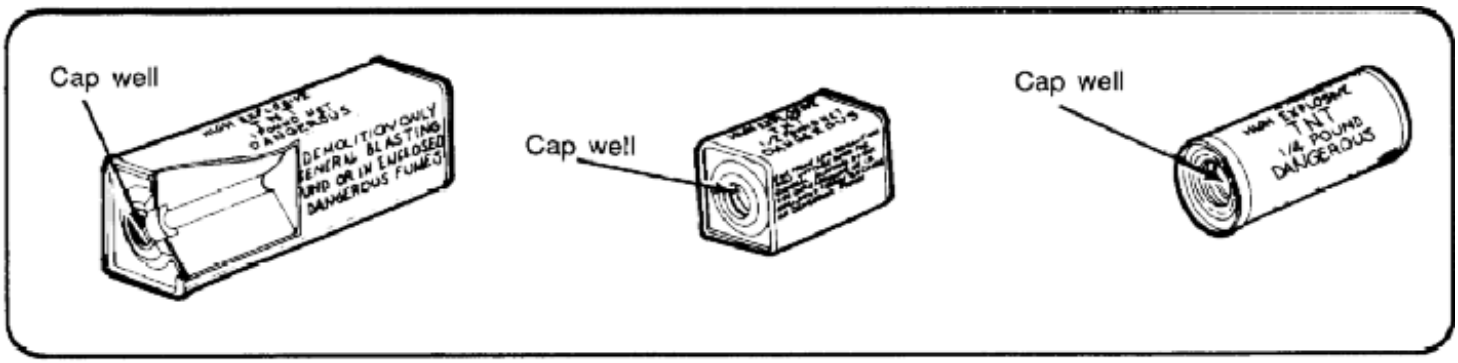


Figure 1-1. TNT block demolition charges

a. Characteristics. TNT block demolitions are available in three sizes (Table 1-2). The ¼-pound block is issued in a

cylindrical, waterproof, olive-drab cardboard container. The ½-pound and l-pound blocks are available in similar rectangular containers. All of the three charges have metal ends with a threaded cap well in one end.

b. Use. TNT block demolition charges are effective for all types of demolition work. However, the ¼-pound charge is primarily for training purposes.

c. Advantages. TNT demolition charges have a high detonating velocity. They are stable, relatively insensitive to shock or friction, and water resistant. They also are conveniently sized, shaped, and packaged.

d. Limitations. TNT block demolition charges cannot be molded and are difficult to use on irregularly shaped targets. TNT is not recommended for use in closed spaces because one of the products of explosion is poisonous gases.

1-7. M112 Block Demolition Charge.

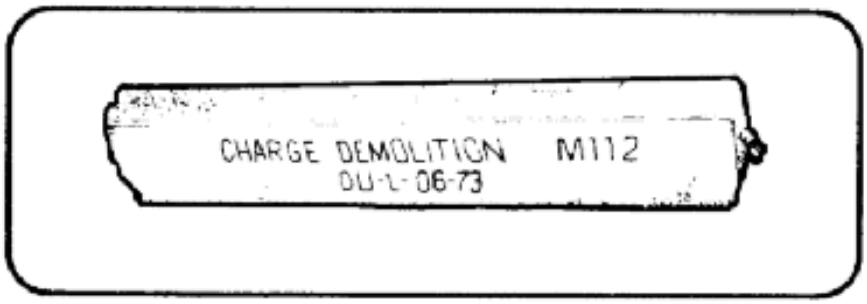


Figure 1-2. M112 block demolition charge

a. Characteristics. The M112 block demolition charge consists of 1.25 pounds of C4 packed in an olive-drab, Mylar-film container with a pressure-sensitive adhesive tape on one surface (Figure1-2). The tape is protected by a peelable paper cover. Table 1-2 (page 1-5) lists additional characteristics of the Ml12 block.

b. Use. The M112 block demolition charge is used primarily for cutting and breaching. Because of its high cutting effect and its ability to be cut and shaped, the M1l2 charge is ideally suited for cutting irregularly shaped targets such as steel. The adhesive backing allows you to place the charge on any relatively flat, clean, dry surface with a temperature that is above the freezing point. The Ml12 charge is the primary block demolition charge presently in use.

WARNING

Composition C4 explosive is poisonous and dangerous if chewed or ingested; its detonation or burning produces poisonous fumes. Cut all plastic explosives with a sharp steel knife on a nonsparking surface.

Do not use shears.

c. Advantages. You can cut to shape the M112 block demolition charge to fit irregularly shaped targets. The color of the wrapper helps camouflage the charge. Molding the charge will decrease its cutting effect.

d. Limitations. The adhesive tape will not adhere to wet, dirty, rusty, or frozen surfaces.

1-8. M118 Block Demolition Charge.

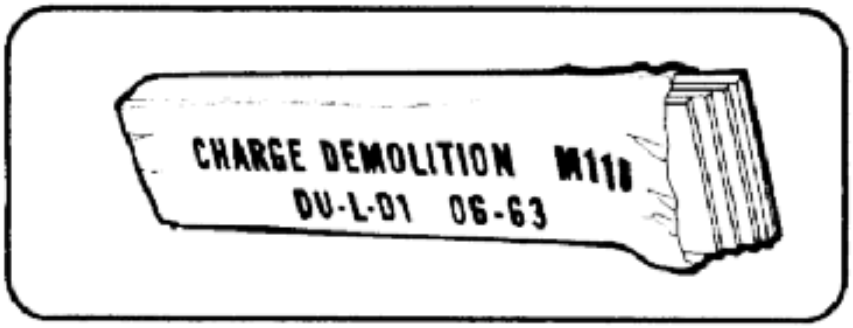


Figure 1-3. M118 block demolition charge

a. Characteristics. The M118 block demolition charge, or sheet explosive, is a block of four ½-pound sheets of flexible explosive packed in a plastic envelope (Figure 1-3). Twenty Ml18 charges and a package of 80 M8 blasting-cap holders are packed in a wooden box. Each sheet of the explosive has a pressure-sensitive adhesive tape attached to one surface. Table 1-2 (page 1 -5) lists additional characteristics for the M118 charge.

b. Use. The Ml18 charges are designed for cutting, especially against steel targets. The sheets of explosive are easily and quickly applied to irregular and curved surfaces and are easily cut to any desired dimension. The Ml18 charge is effective as a small breaching charge but, because of its high cost, it is not suitable as a bulk explosive charge.

c. Advantages. The flexibility and adhesive backing of the sheets allow application to a large variety of targets. You can cut the ½-pound sheets to any desired dimension and apply them in layers to achieve the desired thickness. The Ml18 charge is not affected by water, making it acceptable for underwater demolitions.

d. Limitations. The adhesive tape will not adhere to wet, dirty, rusty, or frozen surfaces.

1-9. M186 Roll Demolition Charge.

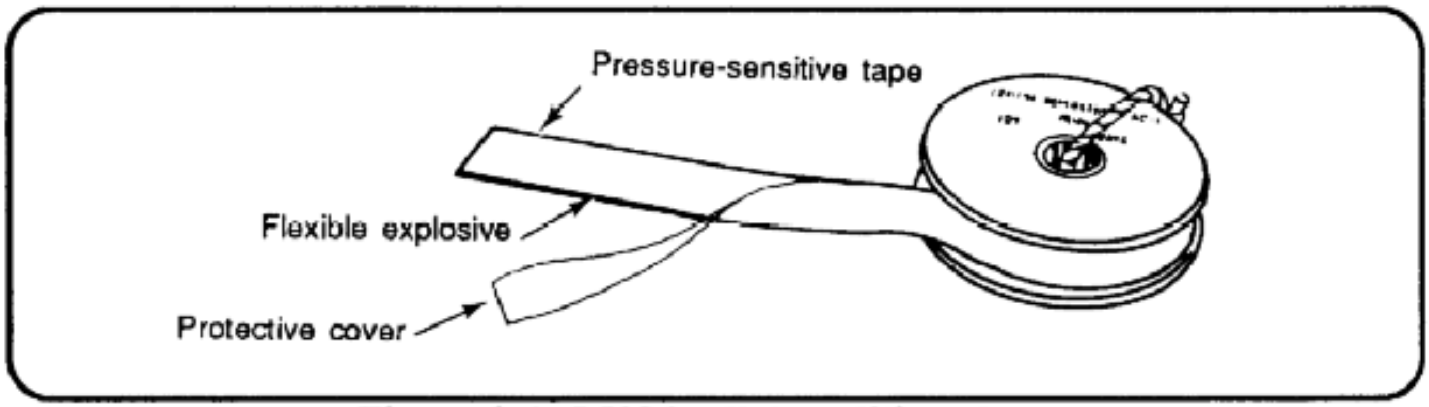


Figure 1-4. M186 roll demolition charge

a. Characteristics. The Ml86 roll demolition charge, shown in Figure 1-4, is identical to the Ml18 block demolition charge except that the sheet explosive is in roll form on a 50-foot, plastic spool. Each foot of the roll provides approximately a half pound of explosive. Included with each roll are 15 M8 blasting cap holders and a canvas bag with carrying strap. Table 1-2 (page 1-5) lists additional characteristics for the M186 charge.

b. Use. Use the M186 roll demolition charge in the same manner as the Ml18 block demolition charge. The Ml86 charge is adaptable for demolishing targets that require the use of flexible explosives in lengths longer than 12 inches.

c. Advantages. The Ml86 roll demolition charge has all the advantages of the Ml18 block demolition charge. You can cut the M186 charge to the exact lengths desired.

d. Limitations. The adhesive backing will not adhere to wet, dirty, rusty, or frozen surfaces.

Forty-Pound, Ammonium-Nitrate Block Demolition Charge

a. Characteristics. Figure 1-5 (page 1-8) shows the 40-pound, ammonium-nitrate block demolition charge or cratering charge. It is a watertight, cylindrical metal container with approximately 30 pounds of an ammonium-nitrate-based explosive and 10 pounds of TNT-based explosive booster in the center, next to the priming tunnels. The two priming tunnels are located to the outside of the container, midway between the ends. One tunnel serves as a cap well for priming the charge with an M6 electric or M7 nonelectric military blasting cap. The other tunnel series as a priming path, with the detonating cord passing through the tunnel and knotted at the end.

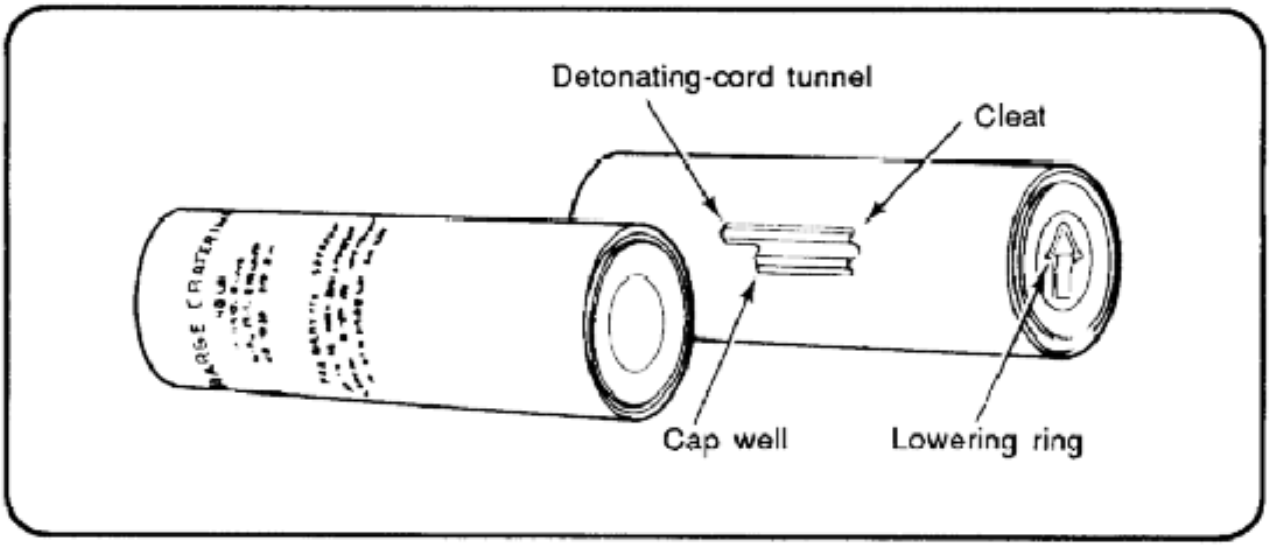


Figure 1-5. Forty-pound, ammonium-nitrate cratering charge

There is a cleat between the tunnels to secure the time blasting fuse, electrical firing wire, or detonating cord. There is a metal ring on the top of the container for lowering the charge into its hole. Table 1-2 (page 1-5) lists additional characteristics for the 40-pound, ammonium-nitrate block demolition charge.

b. Use. This charge is suitable for cratering and ditching operations. Its primary use is as a cratering charge, but it also

is effective for destroying buildings, fortifications, and bridge abutments.

c. Advantages. The size and shape of this charge make it ideal for cratering operations. It is inexpensive to produce compared to other explosives.

d. Limitations. Ammonium nitrate is hydroscopic. When wet, it will not detonate. To ensure detonation, use metal containers showing no evidence of water damage. Detonate all charges placed in wet or damp boreholes as soon as possible.

1-11. Ml Military Dynamite.

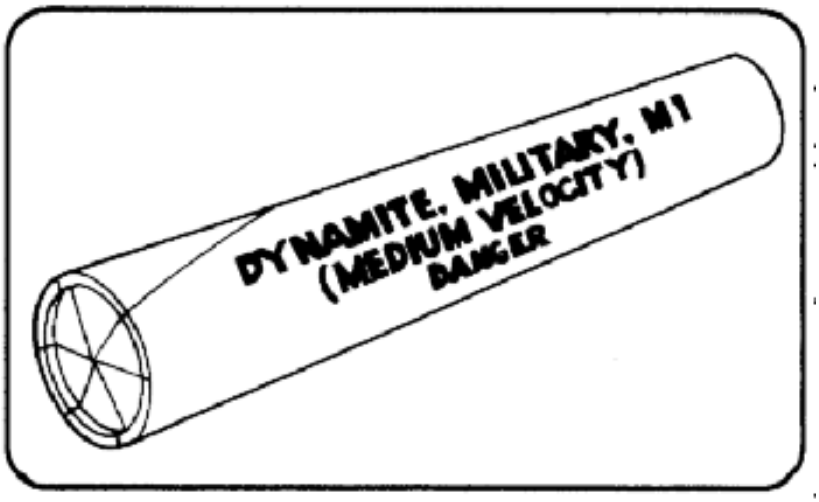


Figure 1-6. M1 military dynamite

a. Characteristics. M1 military dynamite is an RDX-based composite explosive containing no nitroglycerin (Figure 1-6). M 1 dynamite is packaged in ½-pound, paraffin-coated, cylindrical paper cartridges, which have a nominal diameter of 1.25 inches and a nominal length of 8 inches.

Table 1-2 (page 1-5) lists additional characteristics for Ml military dynamite.

b. Use. Ml dynamite's primary uses are military construction,

quarrying, ditching, and service demolition work. It is suitable for underwater demolitions.

c. Advantages. Ml dynamite will not freeze or perspire in storage. The Ml dynamite's composition is not hydroscopic. Shipping containers do not require turning during storage. Ml dynamite is safer to store, handle, and transport than 60-percent commercial dynamite. Unless essential, do not use civilian dynamite incombat areas.

d. Limitations. Ml dynamite is reliable underwater only for 24 hours. Because of its low sensitivity, pack sticks of military dynamite well to ensure complete detonation of the charge. Ml dynamite is not efficient as a cutting or breaching charge.

Section III. Special Demolition Charges and Assemblies

1-12. Shaped Demolition Charge. The shaped demolition charge used in military operations is a cylindrical block of high explosive. It has a conical cavity in one end that directs the cone-lining material into a narrow jet to penetrate materials (Figure 1-7). This charge is not effective underwater, since any water in the conical cavity will prevent the high-velocity jet from forming. To obtain maximum effectiveness, place the cavity at the specified standoff distance from the target, and detonate the charge from the exact rear center, using only the priming well provided. Never dual prime a shaped charge.

a. Characteristics.

(1)Fifteen-Pound, M2A4 Shaped Demolition Charge. The M2A4 charge contains a 0.1 l-pound (50 gram) booster of Composition A3 and a 11.5-pound main charge of

composition

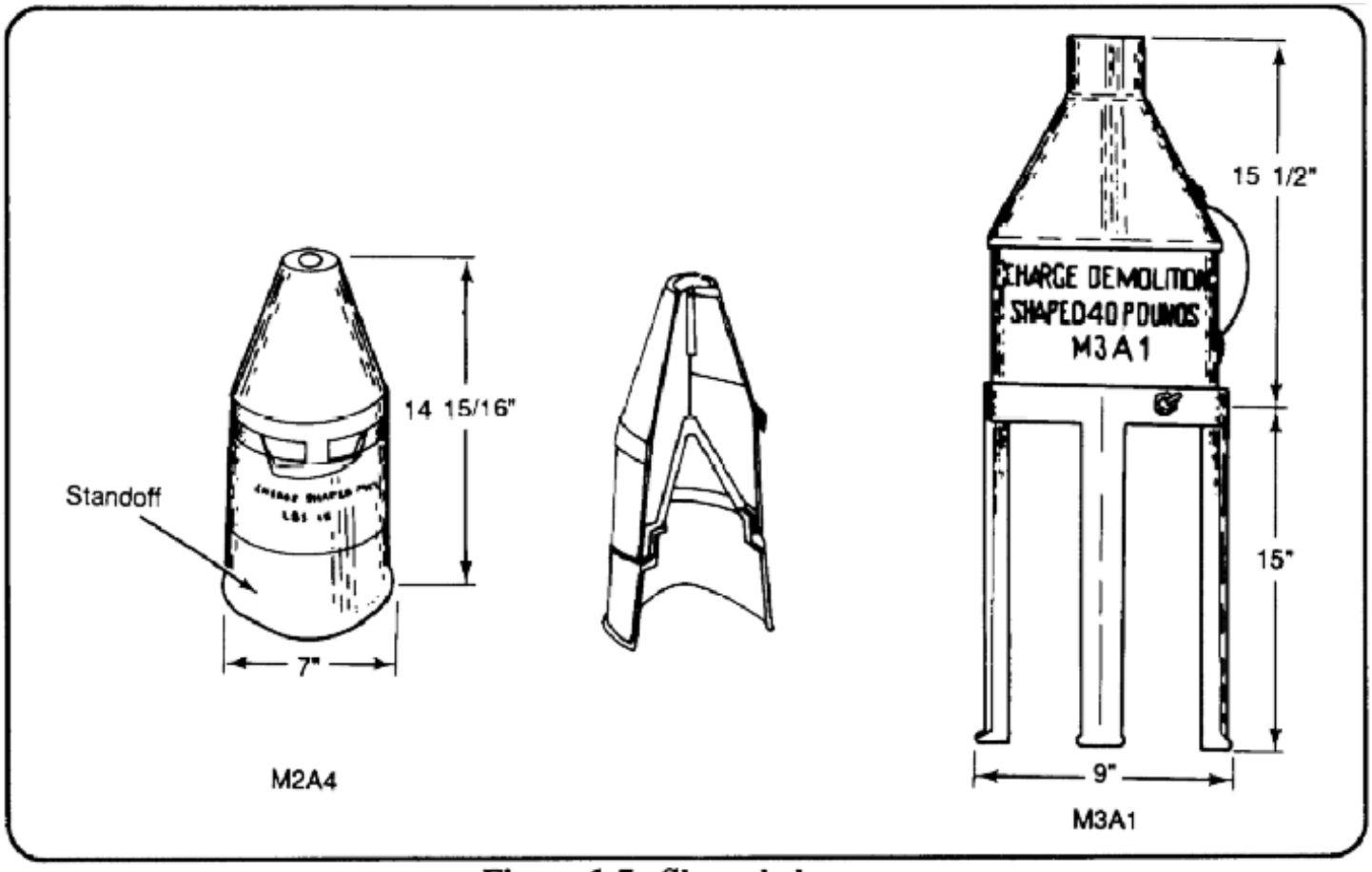


Figure 1-7. Shaped charges

B. It is packaged three charges per wooden box (total weight is 65 pounds). This charge has a moisture-resisting, molded-fiber container. A cylindrical fiber base slips onto the end of the charge to provide a 6-inch standoff distance. The cavity liner is a cone of glass. The charge is 14+5/16 inches high and 7 inches in diameter, including the standoff.

(2) Forty-Pound, M3A1 Shaped Demolition Charge. The M3A1 charge contains a 0.1 l-pound (50 gram) booster of Composition A3 and a 29.5-pound main charge of Composition B. It is packaged one charge per box (total weight is 65 pounds). The charge is in a metal container. The cone liner also is made of metal. A metal tripod provides a 15-inch standoff distance. The charge is 15 ½ inches high and 9 inches in diameter, not including standoff.

b. Use. A shaped demolition charge's primary use is for boring holes in earth, metal, masonry,concrete, and paved and unpaved roads. Its effectiveness depends largely on its shape, composition, and placement. Table 1-3, lists the penetrating capabilities of various materials and the proper standoff distances for these charges.

Table 1-3. Characteristics of boreholes made by shaped charges

Material	Specifications	M2A4 Shaped Charge (15-Pound)*	M3A1 Shaped Charge (40-Pound)**
Armor plate	Penetration	12.00 in	At least 20.00 in
	Average hole diameter	1.50 in	2.50 in
Reinforced concrete	Maximum wall thickness	36.00 in	60.00 in
	Penetration depth in thick walls	30.00 in	60.00 in
	Average hole diameter	2.75 in	3.50 in
	Minimum hole diameter	2.00 in	2.00 in
Concrete pavement (10-inch with 21-inch rock base course)	Optimum standoff	42.00 in	60.00 in
	Minimum penetration depth	44.00 in	71.00 in
	Maximum penetration depth	91.00 in	109.00 in
	Minimum hole diameter	1.75 in	6.75 in
Concrete pavement (3-inch with 24-inch rock base course)	Optimum standoff	42.00 in	—
	Minimum penetration depth	38.00 in	—
	Maximum penetration depth	90.00 in	—
	Minimum hole diameter	3.75 in	—
Permafrost	Hole depth (30-inch standoff)	72.00 in	—
	Hole depth (42-inch standoff)	60.00 in	—
	Hole depth (50-inch standoff)	—	72.00 in
	Hole diameter (42-inch standoff)	1.50 to 6.00 in	—
	Hole diameter (50-inch standoff)	—	5.00 to 8.00 in
	Hole diameter (normal standoff)	4.00 to 30.00 in	7.00 to 30.00 in
Ice	Hole depth (42-inch standoff)	7.00 ft	12.00 ft
	Hole diameter (42-inch standoff)	3.50 in	6.00 in
Soil	Hole depth (30-inch standoff)	7.00 ft	—
	Hole depth (48-inch standoff)	—	7.00 ft
	Hole diameter (30-inch standoff)	7.00 in	—
	Hole diameter (48-inch standoff)	—	14.50 in
Graveled roads	Hole depth (30-inch standoff)	7.00 ft	—
	Hole depth (48-inch standoff)	—	9.00 ft
	Hole diameter (30-inch standoff)	7.00 in	—
	Hole diameter (48-inch standoff)	—	7.00 in

*A dash in the M2A4 Shaped Charge column indicates that a M3A1 shaped charge is required.
**A dash in the M3A1 Shaped Charge column indicates that a M2A4 shaped charge is sufficient.

c. Special Precautions. To achieve the maximum

effectiveness of shaped charges—Center the charge over the target point. Align the axis of the charge with the direction of the desired hole. Use the pedestal to obtain the proper standoff distance.

Suspend the charge at the proper height on pickets or tripods, if the pedestal does not provide the proper standoff distance.

Remove any obstruction in the cavity liner or between the charge and the target.

1-13. M183 Demolition Charge Assembly.

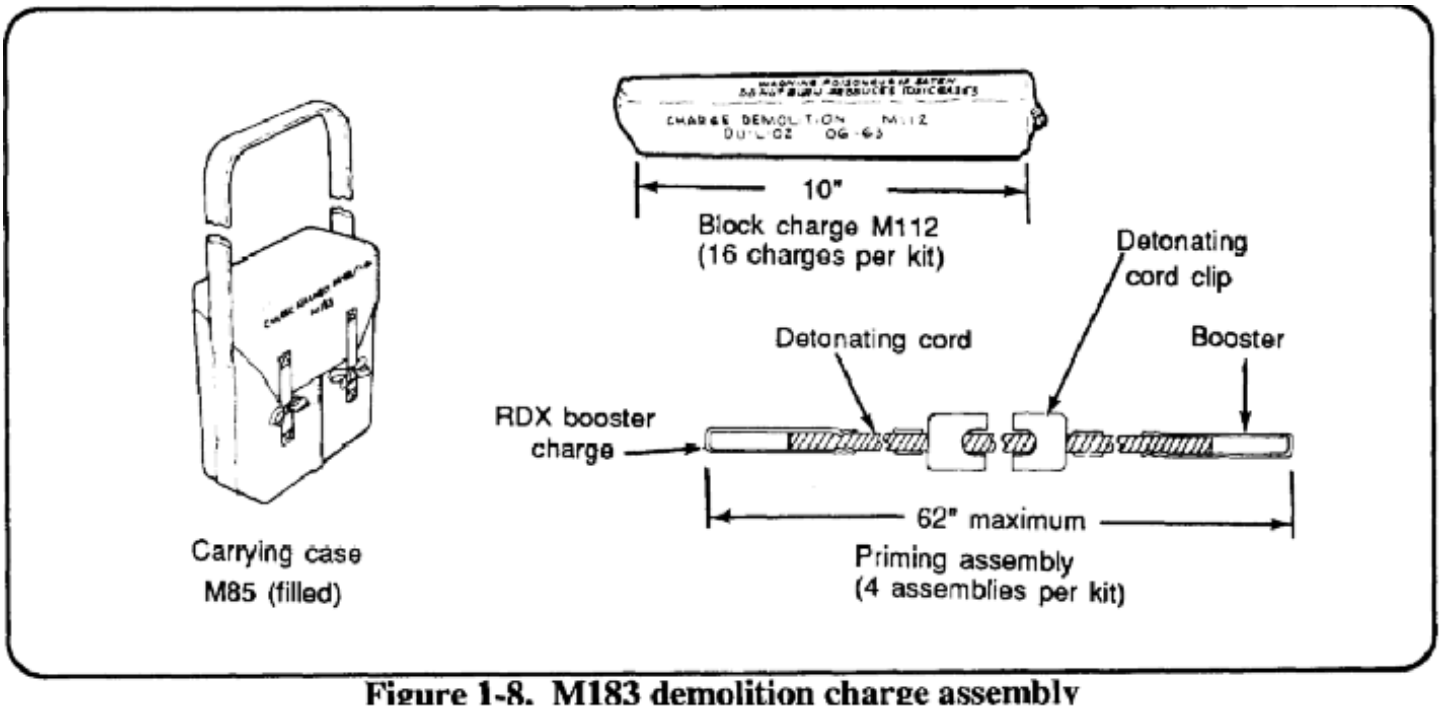


Figure 1-8. M183 demolition charge assembly

a. Characteristics. The Ml83 demolition charge assembly or satchel charge consists of 16 M112 (C4) demolition blocks and 4 priming assemblies. It has a total explosive weight of 20 pounds. The demolition blocks come in two bags, eight blocks per bag. The two bags come in an M85 canvas carrying case. Two M85 cases come in a wooden box 17 1/8 by 11½ by 12½ inches.

Each priming assembly consists of a 5-foot length of detonating cord with an RDX booster crimped to each end and a pair of Ml detonating-cord clips for attaching the priming assembly to a detonating cord ring or line main.

b. Use. The M183 assembly is used primarily forereaching obstacles or demolishing structures when large demolition charges are required (Figure 1-8). The M183 charge also is effective against smaller obstacles, such as small dragon's teeth.

c. Detonation. Detonate the Ml83 demolition charge assembly with a priming assembly and an electric or a nonelectric blasting cap or by using a detonating-cord ring main attached by detonating cord clips.

M1A2 Bangtlore-Torpedo Demolition Kit.

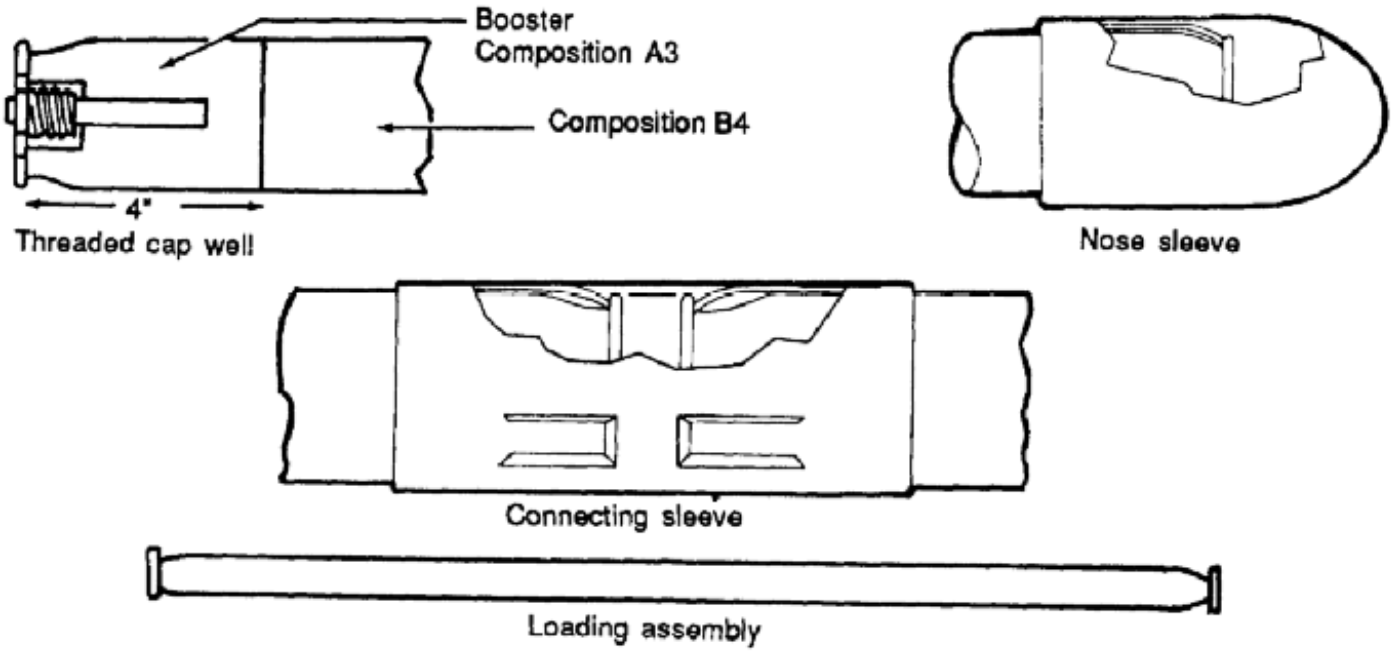


Figure 1-9. M1A2 Bangalore torpedo

a. Characteristics. Each kit consists of 10 loading assemblies,

10 connecting sleeves, and 1 nose sleeve. The loading assemblies, or torpedoes, are steel tubes 5 feet long and 2 1/8 inches in diameter, grooved, and capped at each end (Figure 1-9, page 1-12). The torpedoes have a 4-inch, Composition A3 booster (½ pound each) at both ends of each 5-foot section. The main explosive charge is 10½ pounds of Composition B4. The kit is packaged in a 60¾- by 13¾- by 4 9/16-inch wooden box and weighs 198 pounds.

b. Use. The primary use of the torpedo is clearing paths through wire obstacles and heavy undergrowth. It will clear a 3- to 4-meter-wide path through wire obstacles.

WARNING

The Bangalore torpedo may detonate a live mine when being placed. To prevent detonation of the torpedo during placement, attach the nose sleeve to a fabricated dummy section (approximately the same dimensions as a single Bangalore section) and place the dummy section onto the front end of the torpedo.

c. Assembly. All sections of the torpedo have threaded cap wells at each end. To assemble two or more sections, press a nose sleeve onto one end of one tube, and then connect successive tubes, using the connecting sleeves provided until you have the desired length. The connecting sleeves make rigid joints. The nose sleeve allows the user to push the torpedo through entanglements and across the ground.

d. Detonation. The recommended method to detonate the torpedo is to prime the torpedo with eight wraps of detonating

cord and attach two initiation systems for detonation. Another method for priming the Bangalore torpedo is by inserting an electric or a nonelectric blasting cap directly into the cap well. Do not move the torpedo after it has been prepared for detonation. You may wrap the end with detonating cord prior to placing it, but do not attach the blasting caps until the torpedo is in place.

M180 Demolition Kit (Cratering).

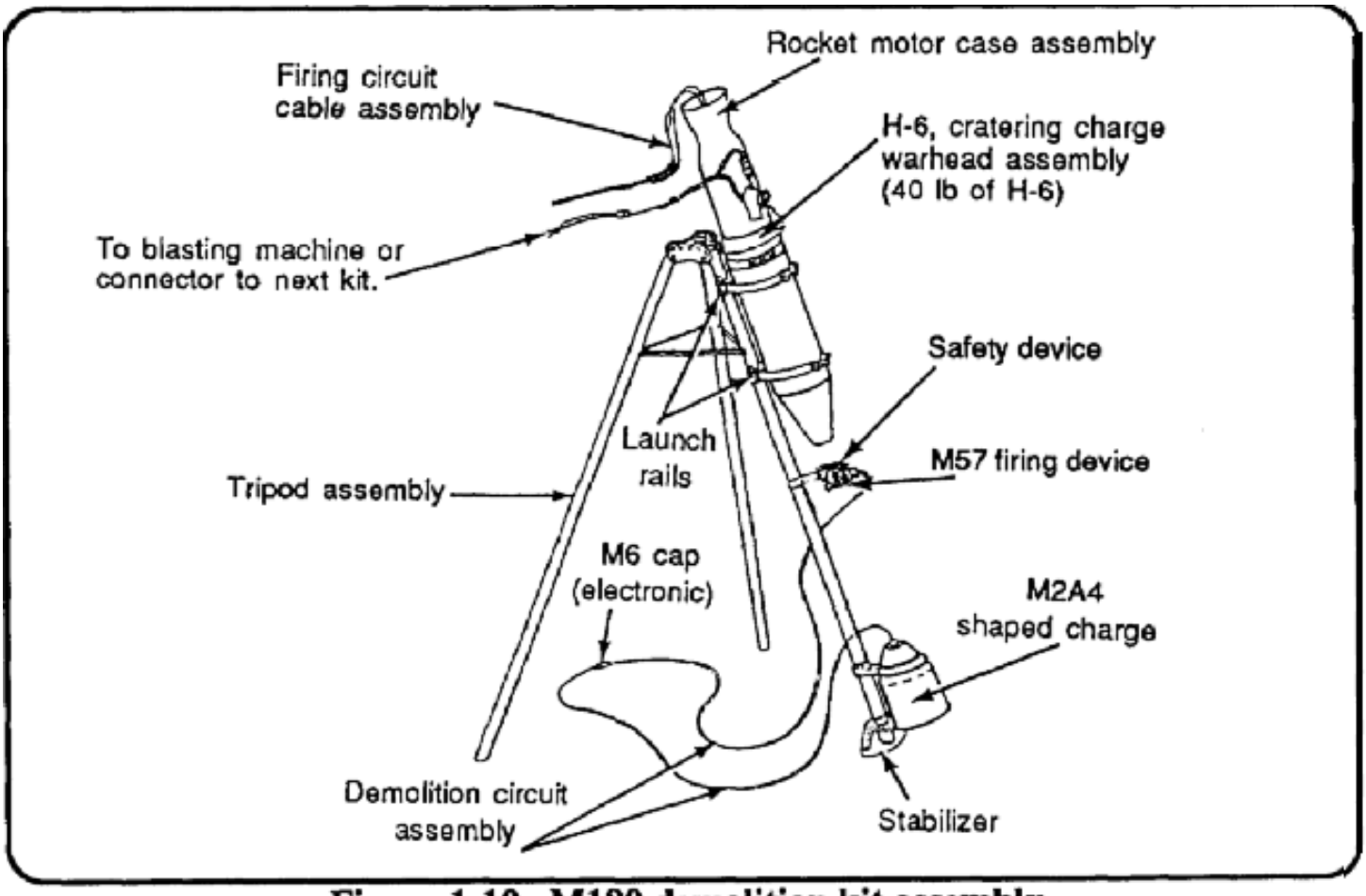


Figure 1-10. M180 demolition kit assembly

a. Characteristics. This kit consists of an M2A4 shaped charge, a modified M57 electrical firing device, a warhead, a rocket motor, a tripod, and a demolition circuit (Figure 1- 10). The shaped charge, firing device, and warhead are permanently attached to the launch leg of the tripod. The rocket motor and the demolition circuit (packed in a wooden

subpack) are shipped separately. The kit weighs approximately 165 pounds (74.25 kilograms). TM 9-1375-213-12-1 provides the assembly procedures, operational description, and maintenance instructions for the Ml80 kit.

b. Use. The M180 is designed to produce a large crater in compacted soil or road surfaces, but not in reinforced concrete, arctic tundra, bedrock, or sandy soil. The charge produces a crater in two stages. The shaped charge blows a pilot hole in the surface. Then, the rocket-propelled warhead enters the hole and detonates, enlarging the pilot hole. Up to five kits can be set up close together and fired simultaneously to produce an exceptionally large crater. Up to 15 kits can be widely spaced and freed simultaneously for airfield pocketing.

WARNING

Regardless of the number of kits used, the minimum safe distances for the M180 cratering kit are 1,200 meters for unprotected personnel and 150 meters for personnel under overhead cover.

c. Detonation. When firing the M180, use the M34 50-cap blasting machine.

Section IV. Demolition Accessories

1-16. Time Blasting Fuse. The time blasting fuse transmits a delayed spit of flame to a non-electric blasting cap. The delay allows the soldier to initiate a charge and get to a safe distance before the explosion. There are two types of fuses: the M700 time fuse and safety fuse. Although safety fuse is not often employed, it is still available.

a. M700 Time Fuse. The M700 fuse is a dark green cord, 0.2 inches in diameter, with a

plastic cover (Figure 1-1 1). The M700 bums at an approximate rate of 40 seconds per foot. However, test the burning rate as outlined in Chapter 2 (paragraph 2-lb(l), page 2-2).

Depending on the date of manufacture, the cover may be smooth or have single yellow bands around the outside at 12- or 18-inch intervals and double yellow bands at 60- or 90-inch intervals. These bands accommodate hasty measuring. The outside covering becomes brittle and cracks easily in arctic temperatures. The M700 time fuse is packaged in 50-foot coils, two coils per package, five packages per sealed container, and eight containers (4,000 feet) per wooden box (30 1/8 by 15 1/8 by 14 7/8 inches). The total package weighs 94 pounds.

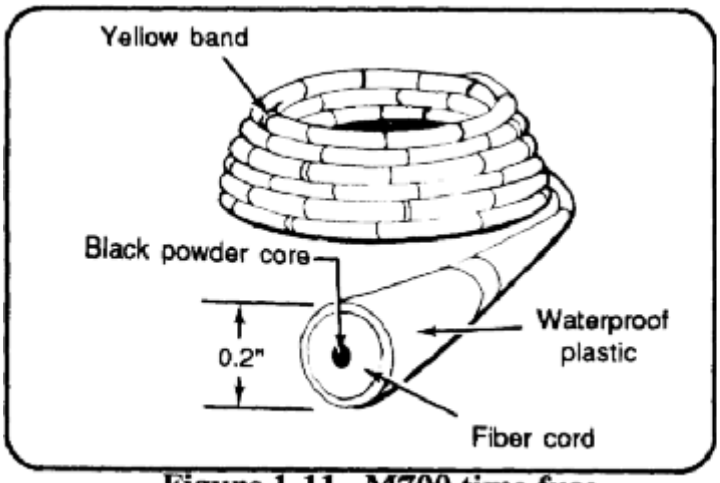


Figure 1-11. M700 time fuse

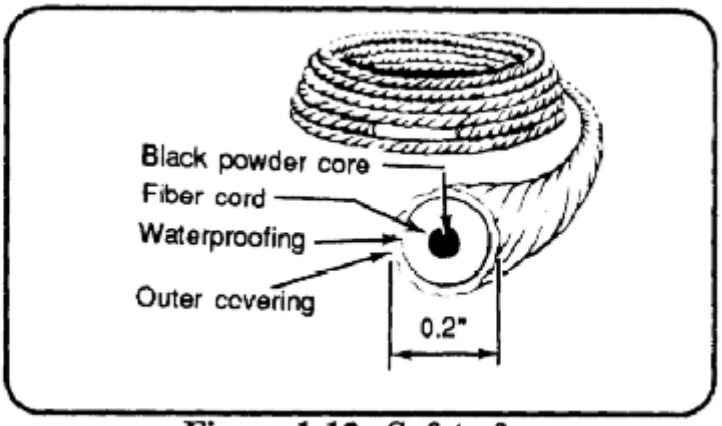


Figure 1-12. Safety fuse

b. Safety Fuse. Safety fuse consists of black powder tightly wrapped with several layers of fiber and waterproofing material. The outside covering becomes brittle and cracks easily in arctic temperatures. The burning rate may vary for

the same or different rolls (30 to 45 seconds per foot) under different atmospheric and climatic conditions. This fuse may be any color, but orange is the most common (Figure 1-12). Test each roll in the area where the charge will be placed (paragraph 2-lb(l), page 2-2). Since safety fuse burns significantly faster underwater, test it underwater before preparing an underwater charge.

Safety fuse is packaged in 50-foot coils, two coils per package, and 30 packages (3,000 feet) per wooden box (24¾ by 15¾ by 12 ½ inches). The total package weighs 93.6 pounds.

Detonating Cord.

a. Characteristics. The American, British, Canadian, and Australian (ABCA) Standardization

Program recognizes this Type 1 detonating cord as the standard detonating cord. Detonating cord (Figure 1-13) consists of a core of high explosive (6.4 pounds of PETN per 1,000 feet) wrapped in a reinforced and waterproof olive-drab plastic coating. This detonating cord is approximately 0.2 inches in diameter, weighs approximately 18 pounds per 1,000 feet, and has a breaking strength of 175 pounds. Detonating cord is functional in the same temperature range as plastic explosive, although the cover becomes brittle at lower temperatures. Moisture can penetrate the explosive filling to a maximum distance of 6 inches from any cut or break in the coating. Water-soaked detonating cord will detonate if there is a dry end to allow initiation. For this reason, cut off and discard the first 6 inches of any new or

used detonating cord that nonelectric blasting caps are crimped to. Also, leave a 6-inch overhang when making connections or when priming charges.

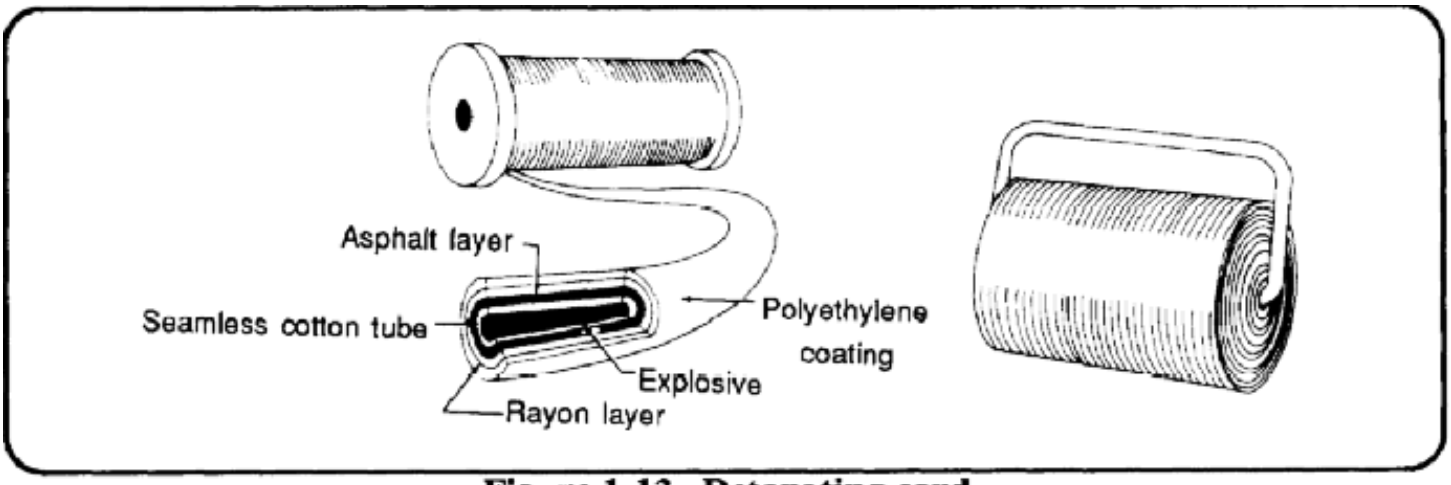


Figure 1-13. Detonating cord

b. Use. Use detonating cord to prime and detonate other explosive charges. When the detonating cord's explosive core is initiated by a blasting cap, the core will transmit the detonation wave to an unlimited number of explosive charges. Chapter 2 explains the use of detonating cord for these purposes.

c. Precautions. Seal the ends of detonating cord with a waterproof sealant when used to fire underwater charges or when charges are left in place several hours before firing. If left for no longer than 24 hours, a 6-inch overlap will protect the remainder of a line from moisture. Avoid kinks or sharp bends in priming, as they may interrupt or change the direction of detonation and cause misfires. Avoid unintended cross-overs of the detonating cord where no explosive connection is intended. To avoid internal cracking do not step on the detonating cord.

Blasting Caps. Blasting caps are for detonating high explosives. There are two types of blasting caps: electric and

nonelectric. They are designed for insertion into cap wells and are also the detonating element in certain firing systems and devices. Blasting caps are rated in power, according to the size of their main charge. Commercial blasting caps are normally Number 6 or 8 and are for detonating the more sensitive explosives, such as commercial dynamite and tetryl.

Special military blasting caps (M6 electric and M7 nonelectric) ensure positive detonation of the generally less sensitive military explosives. Their main charge is approximately double that of commercial Number 8 blasting caps. Never carry blasting caps loose or in uniform pockets where they are subject to shock. Separate blasting caps properly. Never store blasting caps with other explosives. Do not carry blasting caps and other explosives in the same truck except in an emergency (paragraph 6-11, page 6-10).

WARNING

Handle military and commercial blasting caps carefully, as both areextremely sensitive and may explode if handled improperly.

Do not tamper with blasting caps. Protect them from shock and extreme heat.

a. Electric Blasting Caps. Use electric blasting caps when a source of electricity, such as a blasting machine or a battery, is available. Both military and commercial caps may be used.

Military caps (Figure 1-14, page 1-6) operate instantaneously. Commercial caps may operate instantaneously or have a delay feature. The delay time of commercial caps for military

applications ranges from 1 to 1.53 seconds. Electric caps have lead wires of various lengths. The most common lead length is 12 feet. Electric caps require 1.5 amperes of power to initiate. The standard-issue cap is the M6 special electric blasting cap. TM 43-0001-38 gives additional information on blasting caps.

WARNING Do not remove the short-circuiting shunt until ready to test the cap.

Doing this prevents accidental initiation by static electricity.

If the cap has no shunt, twist the lead's bare ends together with at least three 180-degree turns to provide a shunting action.

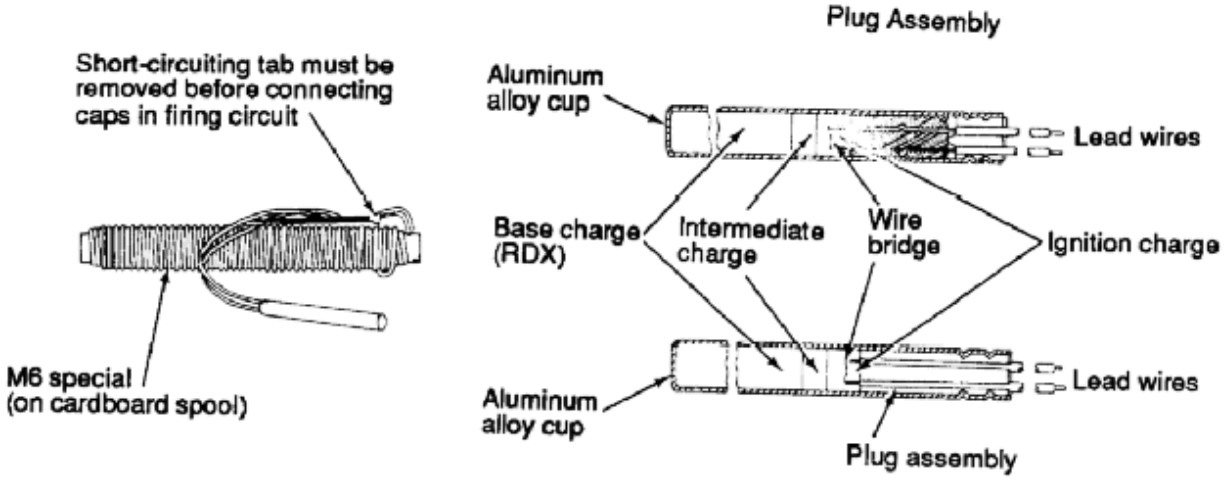


Figure 1-14. Electric blasting caps

b. Non-electric Blasting Caps. Initiate these caps with time-blasting fuse, a firing device, or detonating cord (Figure 1-15). Avoid using non-electric blasting caps to prime underwater charges because the caps are hard to waterproof.

If necessary, waterproof nonelectric blasting caps with a sealing compound. The M7 special nonelectric blasting cap is

the standard issue.

The open end of the M7 special nonelectric blasting cap is flared to allow easy insertion of the time fuse. TM 43-0001-38 gives additional information on blasting caps.

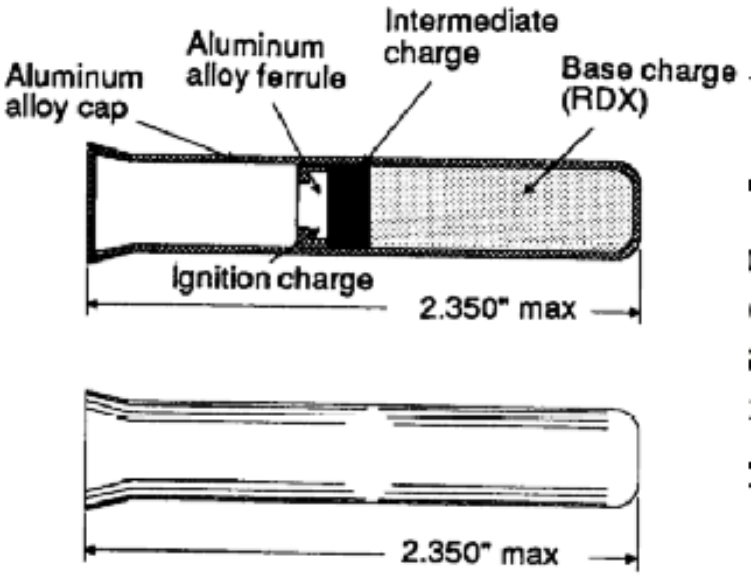


Figure 1-15. Nonelectric blasting cap

MlA4 Priming Adapter. The MIA4 priming adapter is a plastic, hexagonal-shaped device, threaded to fit threaded cap wells. The shoulder inside the threaded end will allow time blasting fuse and detonating cord to pass, but the shoulder is too small to pass a military blasting cap. To accommodate electric blasting caps, the adapter has a lengthwise slot that permits blasting cap lead wires to be quickly and easily installed in the adapter (Figure 1-16).

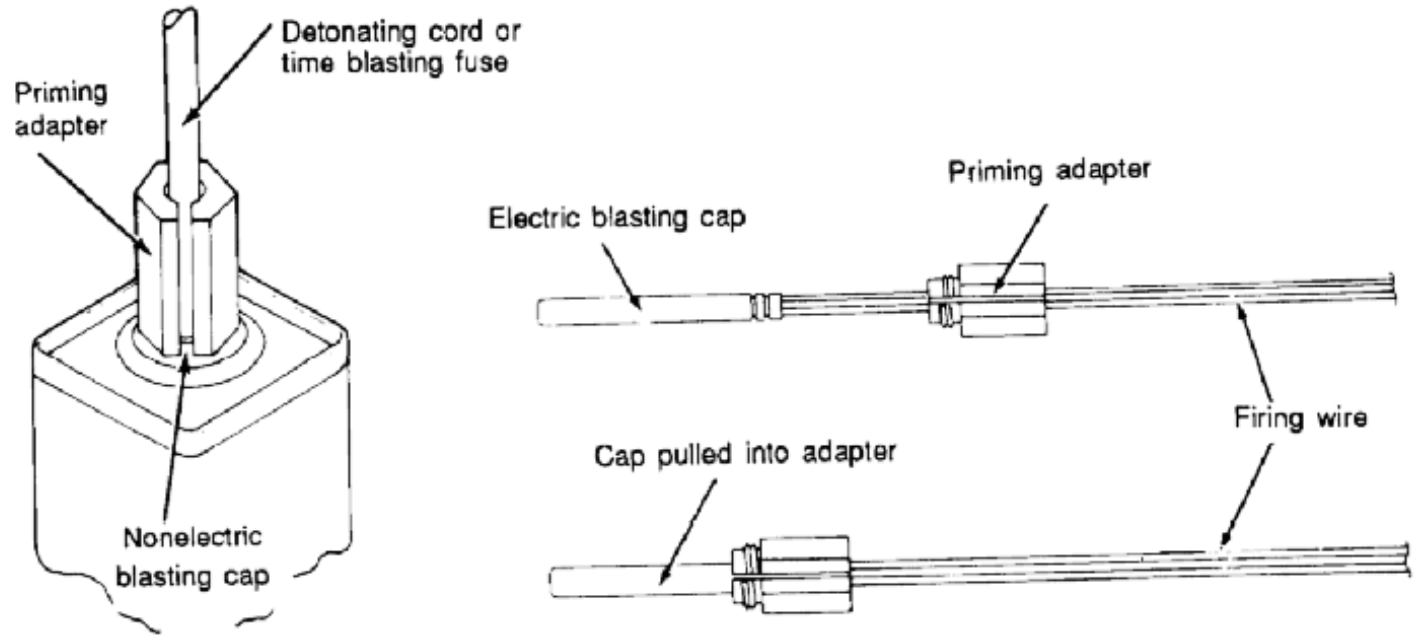


Figure 1-16. M1A4 priming adapter

M8 Blasting Cap Holder. The M8 blasting cap holder is a metal clip designed to attach a blasting cap to a sheet explosive (Figure 1-17). These clips are supplied with Ml18 sheet demolition charges and Ml86 roll demolition charges. The M8 blasting cap holder is also available as a separate-issue item in quantities of 4,000.

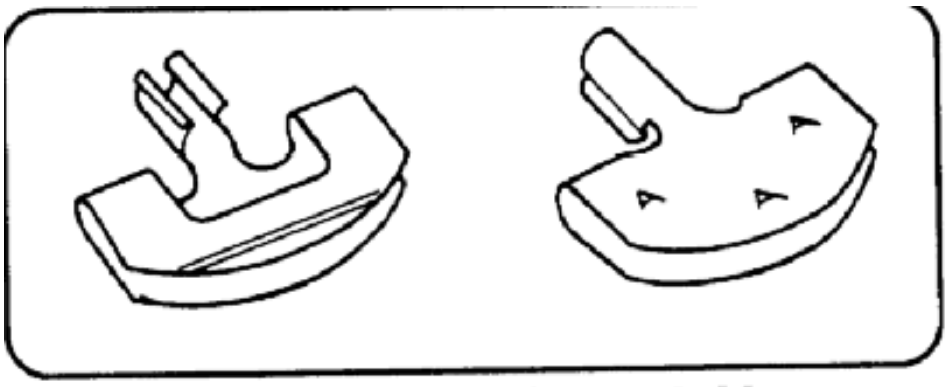


Figure 1-17. M8 blasting cap holder

1-21. Ml Detonating-Cord Clip. The Ml detonating-cord clip is a device for holding two strands of detonating cord together, either parallel or at right angles (Figure 1-18, diagram 1). Using these clips is faster and more efficient than using knots. Knots, if left for extended periods, may loosen and fail to function properly.

a. Branch Lines. Connect a detonating cord branch line by passing it through the trough of the Ml detonating cord clip and through the hole in the tongue of the clip. Next, place the line/ring main into the tongue of the clip so that it crosses over the branch line at a 90-degree angle and ensure the crossover is held secure by the tongue; it may be necessary to bend or form the tongue while doing this.

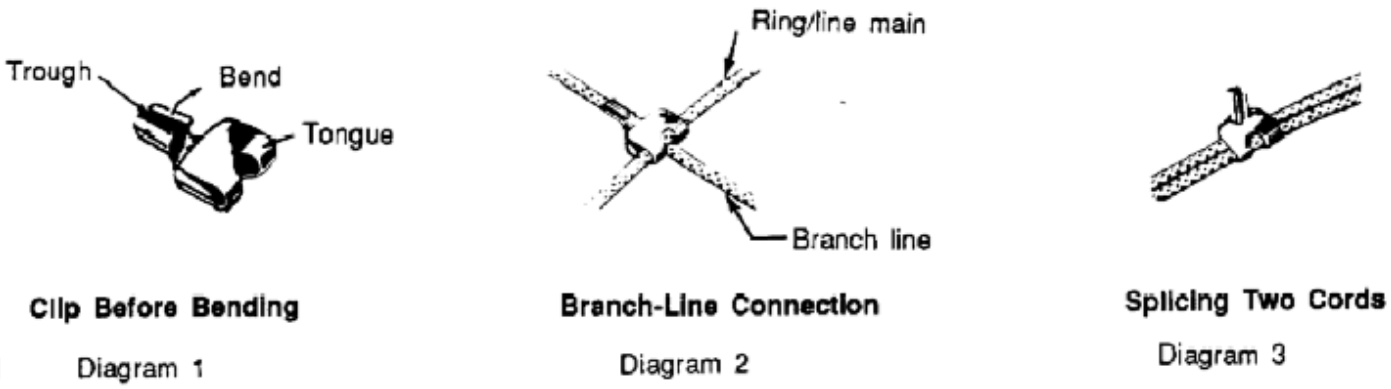


Figure 1-18. M1 detonating-cord clip

b. Splices. Splice the ends of detonating cords by first overlapping them approximately 12 inches. Then secure each loose end to the other cord by using a clip. Finally, bend the tongues of the clips firmly over both strands. Make the connection stronger by bending the trough end of the clip back over the tongue

Ml Adhesive Paste. Ml adhesive paste is a sticky, putty-like substance that is used to attach charges to flat, overhead or vertical surfaces. Adhesive paste is useful for holding charges while tying them in place or, under some conditions, for holding without ties. This paste does not adhere satisfactorily to dirty, dusty, wet, or oily surfaces. Ml adhesive paste becomes useless when softened by water.

Pressure-Sensitive Adhesive Tape.

a. Characteristics. Pressure-sensitive tape is replacing Ml adhesive paste. Pressure sensitive tape has better holding properties and is more easily and quickly applied. This tape is coated on both sides with pressure-sensitive adhesive and requires no solvent or heat to apply. It is available in 2-inch-wide rolls , 72 yards long.

b. Use. This tape is effective for holding charges to dry, clean wood, steel, or concrete.

c. Limitations. This tape does not adhere to dirty, wet, oily, or frozen surfaces.

1-24. Supplementary Adhesive for Demolition Charges.

a. Characteristics. This adhesive is used to hold demolition charges when the target surface is below freezing, wet, or underwater. The adhesive comes in tubes packed in water-resistant, cardboard slide boxes, with wooden applicators

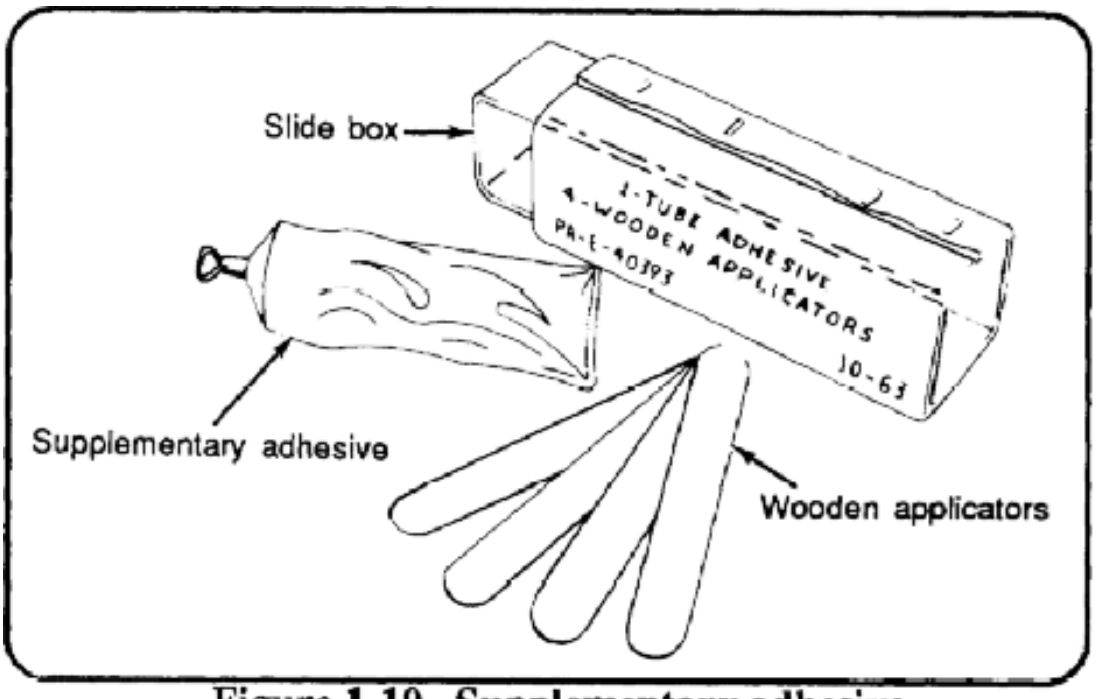


Figure 1-19. Supplementary adhesive

b. Use. Apply the adhesive to the target surface and the

demolition block with a wooden applicator and press the two together.

1-25. Waterproof Sealing Compound. This sealant is for waterproofing connections between time blasting fuses or detonating cords and nonelectric blasting caps. The sealing compound will not make a permanent waterproof seal. Since this sealant is not permanent, fire underwater demolitions as soon as possible after placing them.

1-26. M2 Cap Crimper. Use the M2 cap crimper for squeezing the shell of a nonelectric blasting cap around a time blasting fuse, standard coupling base, or detonating cord.

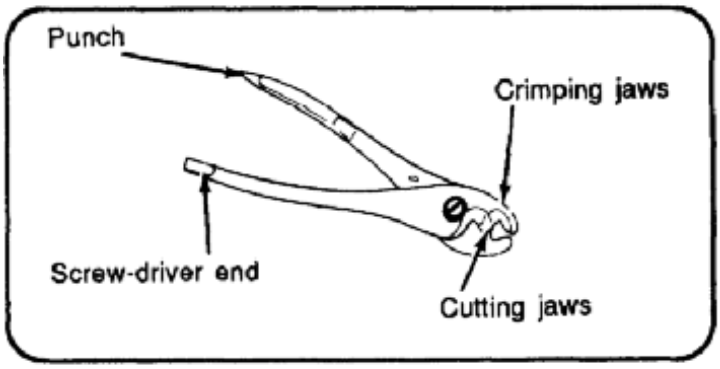


Figure 1-20. M2 cap crimper

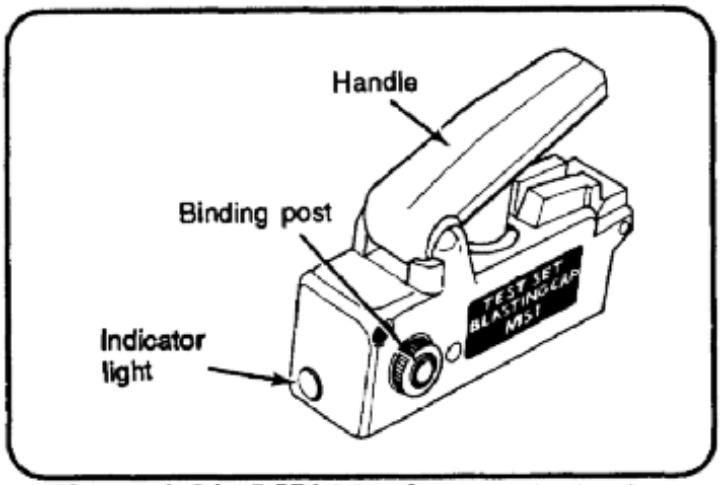


Figure 1-21. M51 blasting-cap test set

Crimp the shell securely enough to keep the fuse, base, or cord from being pulled off, but not so tightly that it interferes with the operation of the initiating device. A stop on the handle helps to limit the amount of crimp applied. The M2 crimper forms a water-resistant groove completely around the blasting cap. Apply a sealing compound to the crimped end of the blasting cap to waterproof it. The rear portion of each jaw is shaped and sharpened for cutting fuses and detonating cords. One leg of the handle is pointed for punching cap wells in

explosive materials. The other leg has a screwdriver end. Cap crimpers are made of a soft, nonsparking metal that conducts electricity. Do not use them as pliers because such use damages the crimping surface. Ensure crimp hole is round (not elongated) and the cutting jaws are not jagged. Keep the cutting jaws clean, and use them only for cutting fuses and detonating cords.

M51 Blasting-Cap Test Set.

a. Characteristics. The test set is a self-contained unit with a magneto-type impulse generator, an indicator lamp, a handle to activate the generator, and two binding posts for attaching firing leads.

The test set is waterproof and capable of operation at temperatures as low as -40 degrees Fahrenheit

b. Use. Check the continuity of firing wire, blasting caps, and firing circuits by connecting the leads to the test-set binding posts and then depressing the handle sharply. If there is a continuous (intact) circuit, even one created by a short circuit, the indicator lamp will flash. When the circuit is open, the indicator lamp will not flash.

c. Maintenance. Handle the test set carefully and keep it dry to assure optimum use.

Before using, ensure the test set is operating properly by using the following procedure:

(1) Hold apiece of bare wire or the legs of the M2 crimpers between the binding posts.

(2) Depress the handle sharply while observing the indicator lamp. The indicator lamp should flash.

(3) Remove the bare wire or crimper legs from the binding posts.

(4) Depress the handle sharply while observing the indicator lamp. This time the indicator lamp should not flash.

(5) Perform both tests to ensure the test set is operating properly.

1-28. Blasting Machines. Blasting machines provide the electric impulse needed to initiate electric blasting-cap operations. When operated, the M32 and M34 models use an alternator and a capacitor to energize the circuit.

a. M32 10-Cap Blasting Machine. This small, lightweight blasting machine produces adequate current to initiate 10 electrical caps connected in series using 500 feet of WD-l cable. To operate the machine, use the following procedure:

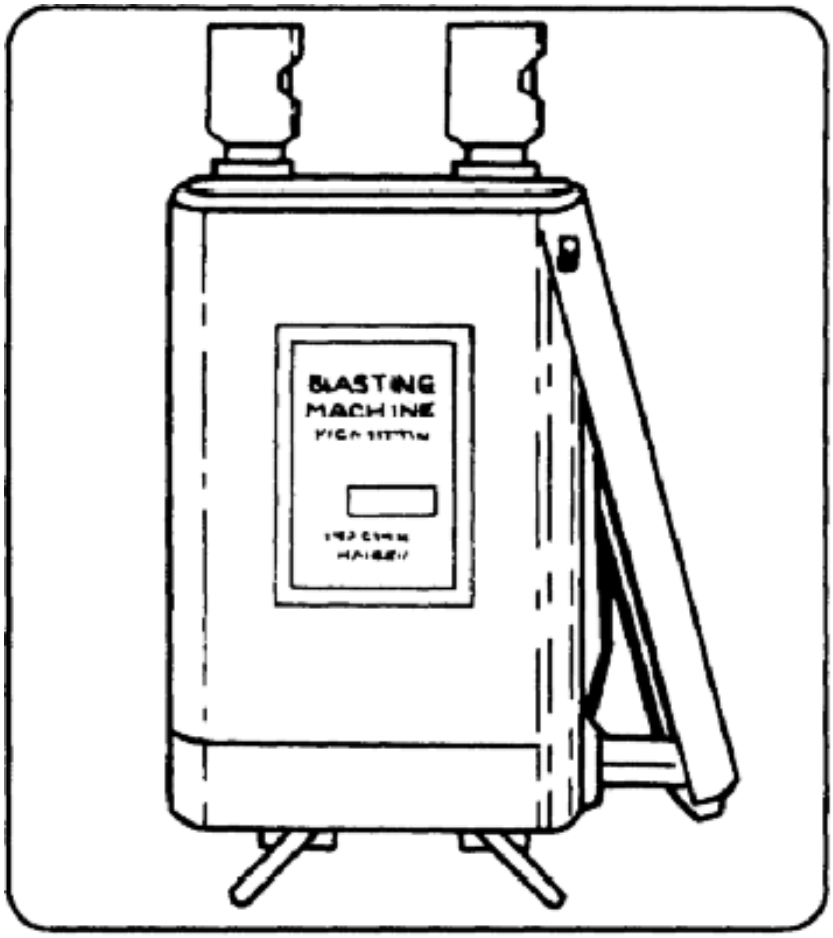


Figure 1-22. M32 blasting machine

(1) Check the machine for proper operation. Release the blasting machine handle by rotating the retaining ring downward while pushing in on the handle. The handle will automatically spring outward from the body of the machine.

(2) Activate the machine by depressing the handle rapidly three or four times until the neon indicator lamp flashes. The lamp is located between the wire terminal posts and cannot be seen until it flashes, since it is covered by green plastic.

(3) Insert the firing wire leads into the terminals by pushing down on each terminal post and inserting the leads into the metal jaws.

(4) Hold the machine upright (terminals up) in either hand,

so the plunger end of the handle rests in the base of the palm and the fingers grasp the machine's body. Be sure to hold the machine correctly, as the handles are easily broken.

(5) Squeeze the handgrip sharply several times until the charge fires. Normally, no more than three or four strokes are required.

b. M34 50-Cap Blasting Machine. This small, lightweight machine produces adequate current to initiate 50 electrical caps connected in a series. It looks like the M32 blasting machine (Figure 1-22) except for a black band around the base and a steel-reinforced actuating handle.

Test and operate the M34 in the same manner as the M32.

Firing Wire and Reels.

a. Types of Firing Wire. Wire for firing electric charges is available in 200- and 500-foot coils.

The two-conductor AWG Number 18 is a plastic-covered or rubber-covered wire available in 500-foot rolls. This wire is wound on an RL39A reel unit. The single conductor. AWG Number 20 annunciator wire is available in 200-foot coils and is used to make connections between blasting caps and firing wire. The WD- l/TT communication wire will also work, but it requires a greater power source if more than 500 feet are used (blasting machines will not initiate the full-rated number of caps connected with more than 500 feet of WD-l/TT wire).

As a rule of thumb, use 10 less caps than the machine's rating for each additional 1,000 feet of WD-1/TT wire employed.

b. Reel. The RL39A reel, with spool, accommodates 500 feet of wire. The reel has a handle assembly, a crank, an axle, and two carrying straps (Figure 1-23). The fixed end of the wire extends from the spool through a hole in the side of the drum and fastens to two brass thumb-out terminals.

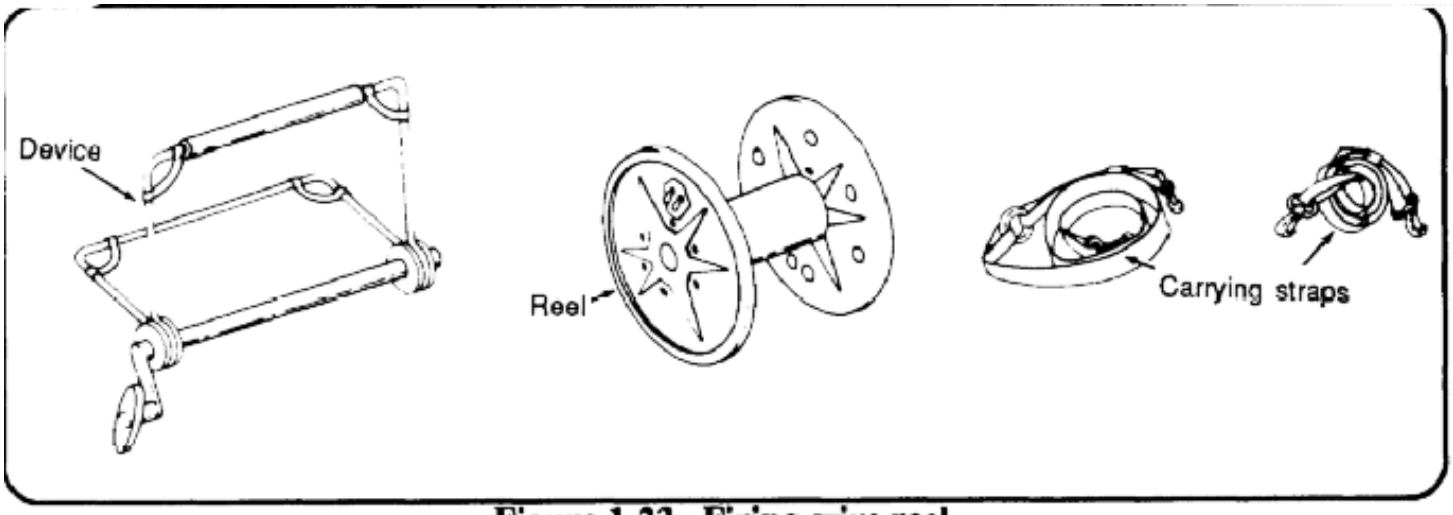


Figure 1-23. Firing-wire reel

The carrying handles are two U-shaped steel rods. A loop at each end encircles a bearing assembly to accommodate the axle. The crank is riveted to one end of the axle, and a cotter pin holds the axle in place on the opposite end.

1-30. Firing Devices and Other Accessory Equipment

a. M60 Weatherproof Fuze Igniter. This device is for igniting timed blasting fuse in all weather conditions, even underwater, if properly waterproofed. Insert the fuse through a rubber sealing grommet and into a split collet. This procedure secures the fuse when the end capon the igniter is tightened. Pulling the pull ring releases the striker assembly, allowing the firing pin to initiate the primer,

igniting the fuse. Chapter 2 gives detailed operating instructions for the M60 igniter.

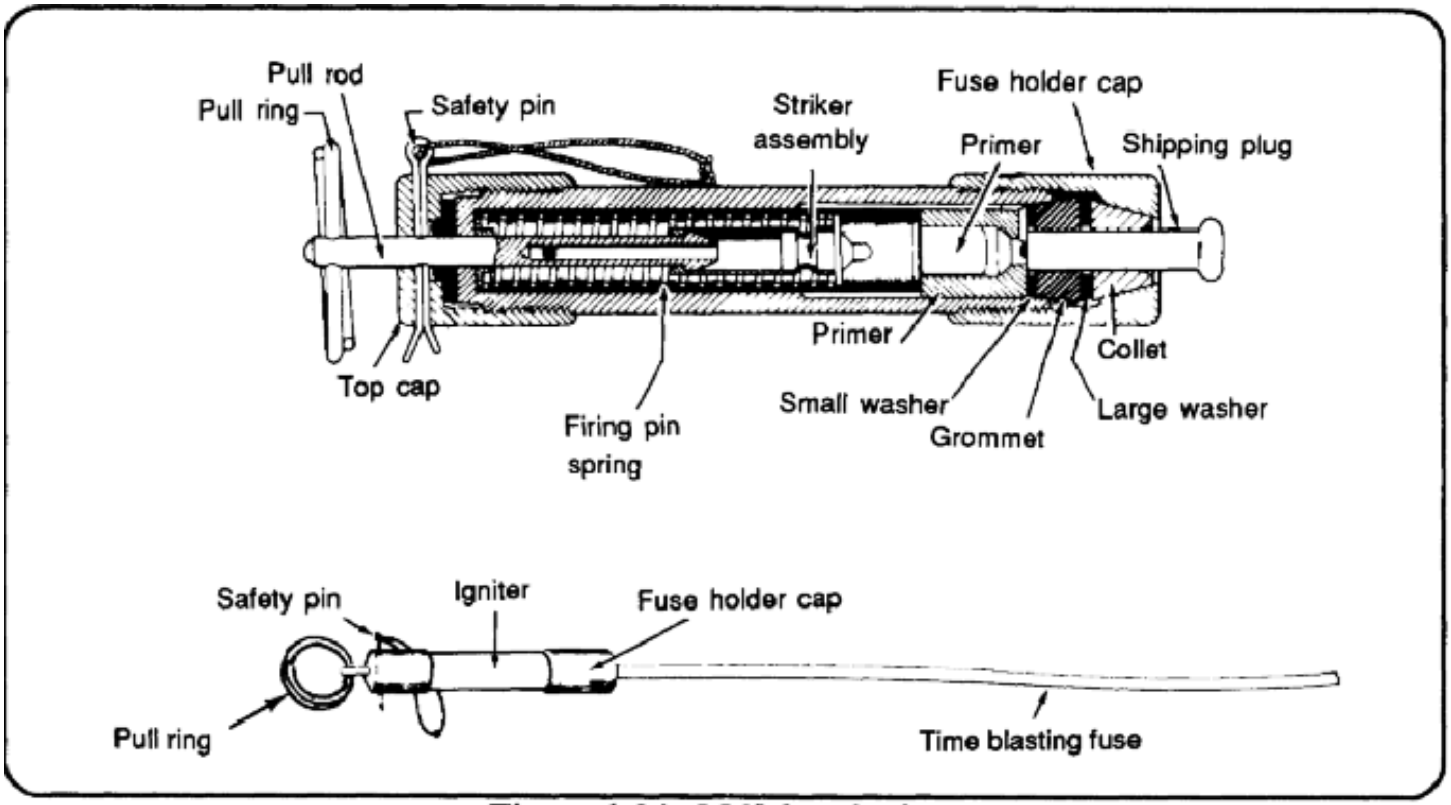


Figure 1-24. M60 fuze igniter

b. Demolition Equipment Set. This set (Electric and Nonelectric Explosive Initiating Demolition Equipment Set) is an assembly of tools necessary for performing demolition operations.

Table 1-4. Demolition equipment set

Quantity	Nomenclature	Quantity	Nomenclature
3	Bag, Demolition Equipment	1	Machine, Blasting, M34
5	Box, Blasting Cap, Plastic, 10-Cap	2	Pliers, Lineman's, w/ Side Cutter, 8-Inch
1	Chest, Demo, Engr Plt, M1931	1	Pliers, Diagonal-Cutting, 6-Inch
4	Crimper, Blasting Cap, M2	4	Reel, Cable
2	Knife, Pocket, w/ Can Opener and Punch	1	Machine, Cable-Reeling, Manual
2	Knife, Pocket, w/ Screwdriver and Wire Scraper	1	Set, Blasting-Cap Test, M51
1	Shears, Metal-Cutting, Manual, 8-Inch	**NOTE**: The individual items listed in this set are available separately.	
2	Tape, Measuring, Steel, Millimeters and Inches		
1	Tape, Measuring, Plastic-Coated, 100-Foot		

NEXT

BACK TO COMMERCIAL EXPLOSIVES

Chapter 2

Initiating Sets, Priming, and Firing Systems

Section I. Initiating Sets

WARNING

Refer to the safety procedures in Chapter 6 before undertaking any demolitions mission.

Non-electric Initiation Sets.

a. Components Assembly. A non-electric system uses a non-electric blasting cap as the initiator. The initiation set consists of a fuse igniter (produces flame that lights the time fuse), the time blasting fuse (transmits the flame that fires the blasting cap), and a non-electric blasting cap (provides shock adequate to detonate the explosive) (Figure 2-1). When combined with detonating cord, a single initiation set can fire multiple charges.

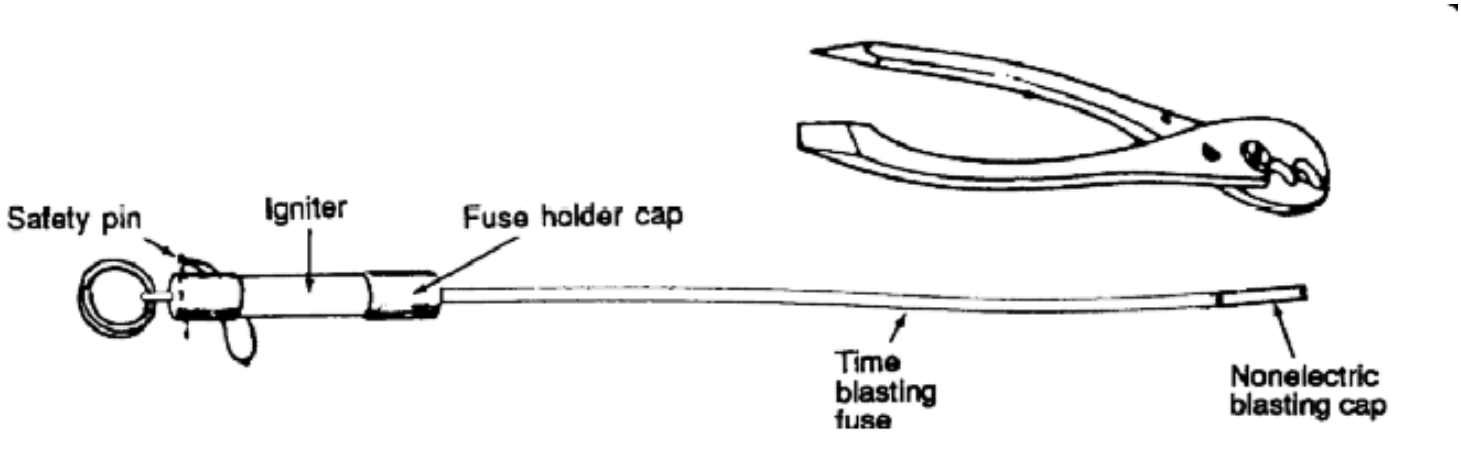


Figure 2-1. Nonelectric initiation set

b. Preparation Sequence. Preparing demolitions for non-electric initiation follows a specified process. This process

includes—

Step 1. Checking the time fuse.

Step 2. Preparing the time fuse.

Step 3. Attaching the fuse igniter.

Step 4. Installing the primer adapter.

Step 5. Placing the blasting cap

(1) Checking Time Fuse. Test every coil of fuse, or remnant of a coil, using the burning-rate test prior to use.

One test per day per coil is sufficient.

Never use the first and last 6 inches of a coil because moisture may have penetrated the coil to this length. Using an M2 crimper, cut and discard a 6-inch length from the free end of the fuse

(Figure 2-2). Cut off and use a 3-foot length of the fuse to check the burning rate. Ignite the fuse and note the time it takes for the fuse to burn. Compute the burning rate per foot by dividing the bum time in seconds by the length in feet. If the test bum does not fall within ± 5 seconds of a 40-second-per-foot burn rate, perform another test to verify your results.

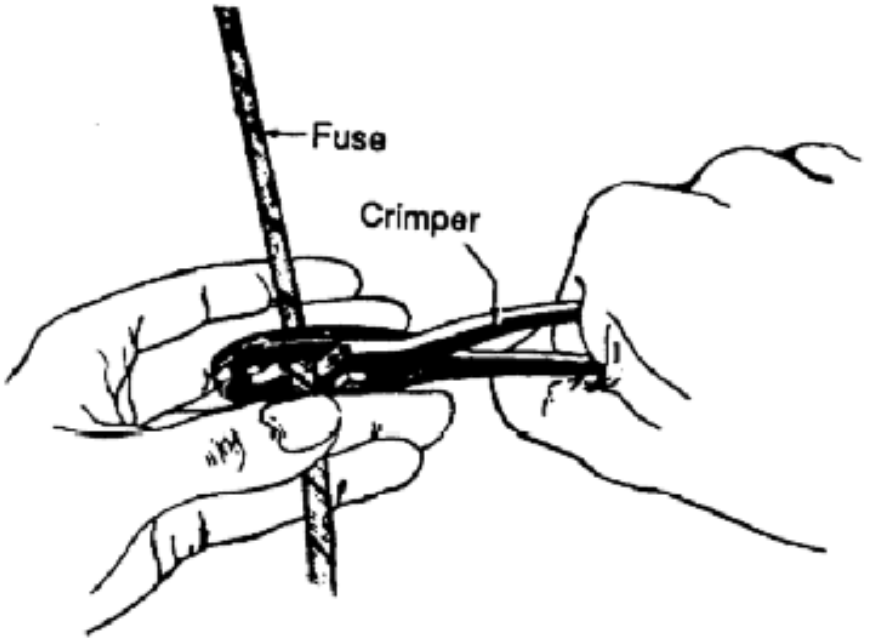


Figure 2-2. Cutting time fuse

WARNING

Test burn a 3-foot length of time blasting fuse to determine the exact rate prior to use.

(2) Preparing Time Fuse. Cut the fuse long enough to allow the person detonating the charge to reach safety (walking at a normal pace) before the explosion. Walk and time this distance prior to cutting the fuse to length. The formula for determining the length of time fuse required is—

$$\frac{\text{Time Required(min) X 60 (sec/min)}}{\text{Burn Rate (sec/ft)}} = \text{Fuse Length (ft)}$$

Make your cut squarely across the fuse. Do not cut the fuse too far in advance, since the fuse may absorb moisture into the open ends. Do not allow the time fuse to bend sharply, as you may crack the black powder core, resulting in a

misfire.

(3) Attaching Fuse Igniter. To attach an M60 weatherproof fuze igniter, unscrew the fuse holder cap two or three turns, but do not remove the cap. Press the shipping plug into the igniter to release the split collet (Figure 1-24, page 1-22). Rotate and remove the plug from the igniter. Insert the free end of the time fuse as far as possible into the space left by the removed shipping plug.

Sufficiently tighten the holder cap to hold the fuse and weatherproof the joint.

(4) Installing Priming Adapter. If you use a priming adapter to hold a non-electric blasting cap, place the time fuse through the adapter before installing (crimping) the blasting cap onto the fuse.

Ensure the adapter threads are pointing to the end of the time fuse that will receive the blasting cap.

(5) Preparing Blasting Caps.

(a) Inspection. Hold the cap between the thumb and ring finger of one hand, with the forefinger of the same hand on the closed end of the blasting cap. Inspect the blasting cap by looking into the open end. You should see a yellow-colored ignition charge. If dirt or any foreign matter is present, do the following:

Aim the open end of the cap at the palm of the second hand.

Gently bump the wrist of the cap-holding hand against the wrist of the other hand.

If the foreign matter does not dislodge, do not use the cap.

(b) Placing and crimping. Use this procedure for installing blasting caps onto fuse. Using this procedure will allow accurate crimping, even in darkness, because finger placement guides the crimpers to the open end of the blasting cap. Use the following procedures to attach a non-electric blasting cap onto time fuse:

Hold the time blasting fuse vertically with the square-cut end up, and slip the blasting cap gently down over the fuse so the flash charge in the cap touches the fuse.

WARNING

If the charge in the cap is not in contact with the fuse, the fuse may not ignite the cap (misfire). Never force a time fuse into a blasting cap, for example, by twisting or any other method. If the fuse end is flat or too large to enter the blasting cap freely, roll the fuse between the thumb and fingers until it will freely enter the cap. A rough, jagged-cut fuse inserted in a blasting cap can cause a misfire. If the cutting jaws of the M2 crimper are unserviceable, use a sharp knife to cut the fuse. When using a knife to cut fuse squarely, cut the fuse against a solid, non-sparking surface such as wood.

While applying slight pressure with the forefinger on the

closed end of the cap, grasp the fuse with the thumb and ring finger. Using the opposite hand, grasp the crimpers. Place the crimping jaws around the cap at a point 1/8 to ¼ inch from the open end. The thumb and ring finger that hold the fuse will be below the crimpers. Rest the second finger of the hand holding the fuse on top of the crimpers to prevent the crimpers from sliding up the cap.

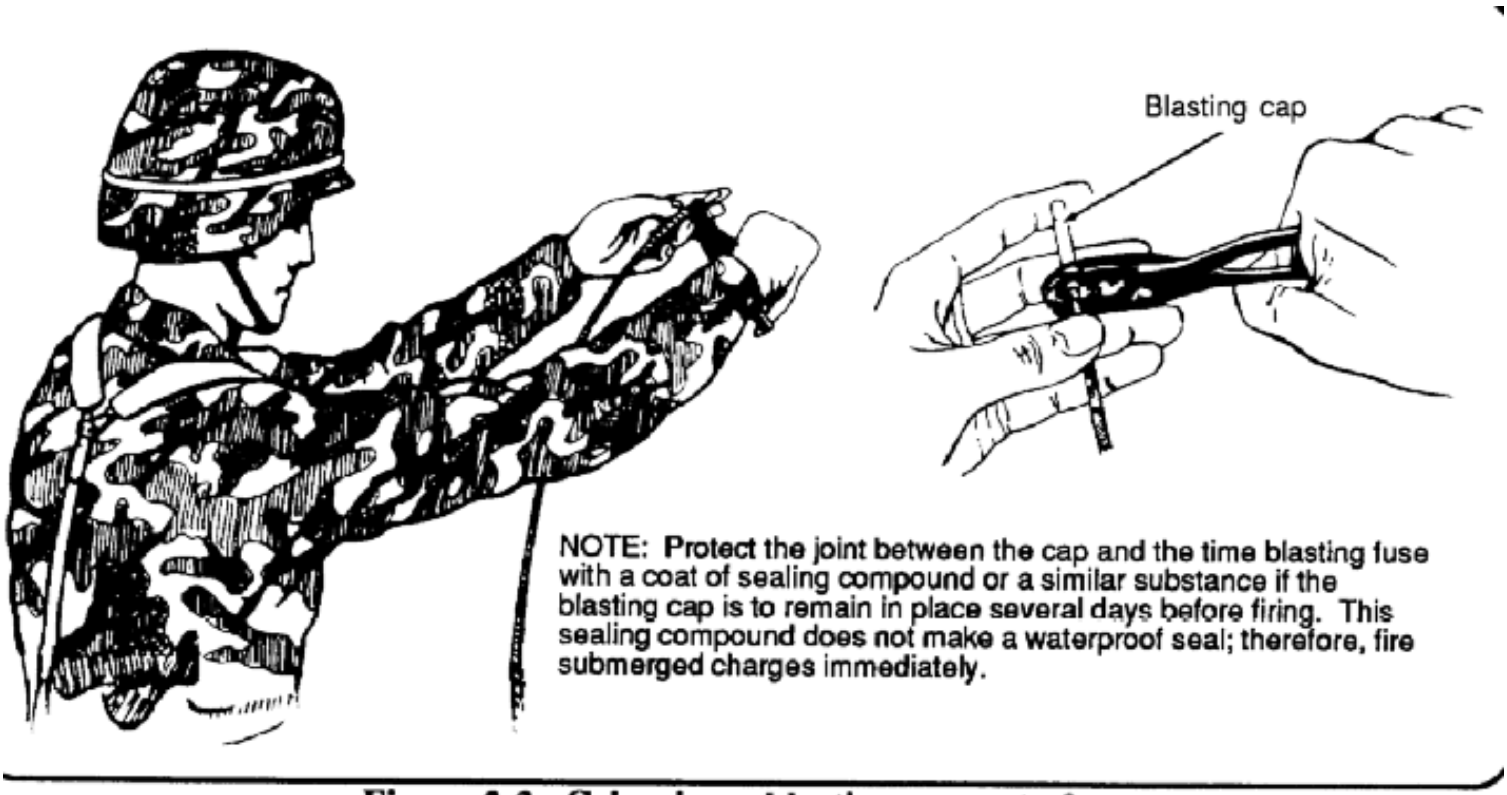

Blasting cap
NOTE: Protect the joint between the cap and the time blasting fuse with a coat of sealing compound or a similar substance if the blasting cap is to remain in place several days before firing. This sealing compound does not make a waterproof seal; therefore, fire submerged charges immediately.

Figure 2-3. Crimping a blasting cap onto fuse

Extend both arms straight out while rotating the hands so that the closed end of the blasting cap is pointing away from the body and from other personnel.

Crimp the blasting cap by firmly squeezing the M2 crimper handles together, maintaining eye contact with the blasting cap. Inspect the crimp after you have finished. Ensure that the fuse and cap are properly joined by gently trying to pull them apart

NOTE: Attach the M60 fuze igniter to the time fuse before crimping a blasting cap to the opposite end. Do not remove the safety pin until you are ready to detonate the charge.

WARNING

Do not crimp too close to the explosive end of the blasting cap; doing this may cause the cap to detonate.

Point the cap out and away from the body during crimping.

NOTE: If the cap is to remain in place several days before firing, protect the joint between the cap and the timed blasting fuse with a coat of sealing compound or similar substance. This sealing compound will not make a waterproof seal; therefore, fire submerged charges immediately.

NOTE: See paragraph 6-8 (page 6-8) for procedures on handling non-electric misfires.

c. Fuse Initiation. To fire the assembly, hold the M60 igniter in one hand and remove the safety pin with the other. Grasp the pull ring and give it a quick, hard pull. In the event of a misfire, reset the M60 by pushing the plunger all the way in, rotate it left and right, and attempt to fire as before.

WARNING

Water can enter through the vent hole in the pull rod when attempting to reset the igniter under water.

This will prevent the fuse igniter from working after resetting.

NOTE: If a fuze igniter is not available, light the time blasting fuse with a match.

Split the fuse at the end (Figure 2-4) and place the head of an unlit match in the powder train. Light the inserted match head with a flaming match, or rub the abrasive on the match box against it. It may be necessary to use two match heads during windy conditions.

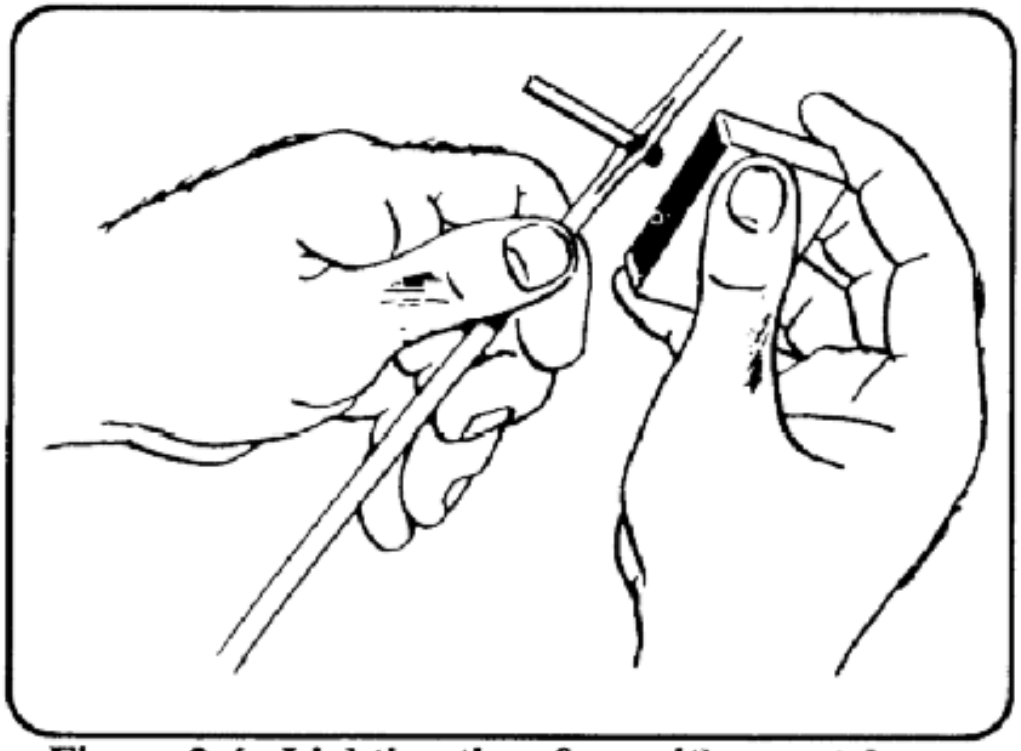


Figure 2-4. Lighting time fuse with a match

Electric Initiation Sets.

a. Preparation Sequence. Use the process below to make an electric initiation set. This process includes—

Testing and maintaining control of the blasting machine.

Testing the M51 blasting-cap test set.

Testing the firing wire on the reel, shunted and unshunted.

Laying out the firing wire completely off the reel.

Retesting the firing wire, shunted and unshunted.

Testing the blasting caps.

Connecting the series circuit.

Connecting the firing wire.

Testing the entire circuit.

Priming the charges.

b. Components Assembly. An electric system uses an electric blasting cap as the explosion initiator. The initiation set consists of an electric blasting cap, the firing wire, and a blasting machine

(Figure 2-5) An electric impulse (usually provided by a blasting machine) travels through the firing wires and blasting cap leads, detonating the blasting cap which initiates the explosion. Radio waves can also detonate electric blasting caps. Therefore, observe the minimum safe distances listed in Chapter 6 (page 6-5) at all times. When combined with detonating cord, a single initiation set can fire multiple charges. TM 9-1375-213-34 provides detailed information about electric blasting equipment.

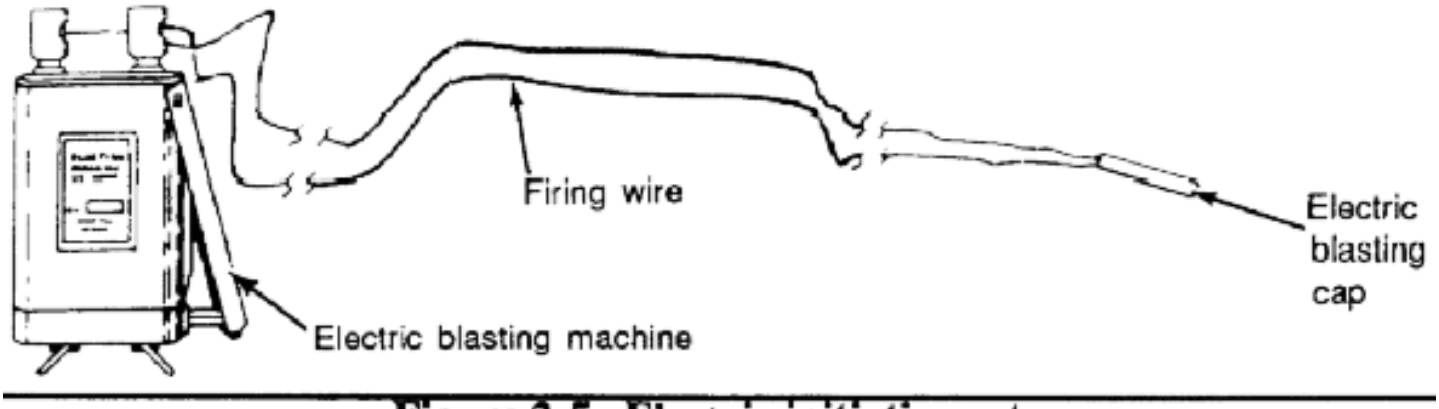


Figure 2-5. Electric initiation set

Always follow the procedure below when preparing an electric initiation set:

(1) Testing and Maintaining Control of Blasting Machine.

(a) Test the blasting machine to ensure it is operating properly (paragraph 1-28, page 1-20).

(b) Control access to all blasting machines. The supervisor is responsible for controlling all blasting machines.

(2) Testing M51 Blasting-Cap Test Set

(a) Check the M51 test set to ensure it is operating properly (paragraph 1-27, page 1-19).

(b) Perform both the open- and short-circuit tests.

(3) Testing Firing Wire on the Reel.

(a) Separate the firing wire leads at both ends and connect the leads at one end to the posts of the MS 1 test set. Squeeze-tie test-set handle. The indicator lamp should NOT flash. If it does, the lamp’s flash indicates a short circuit in the firing wire (Figure 2-6).

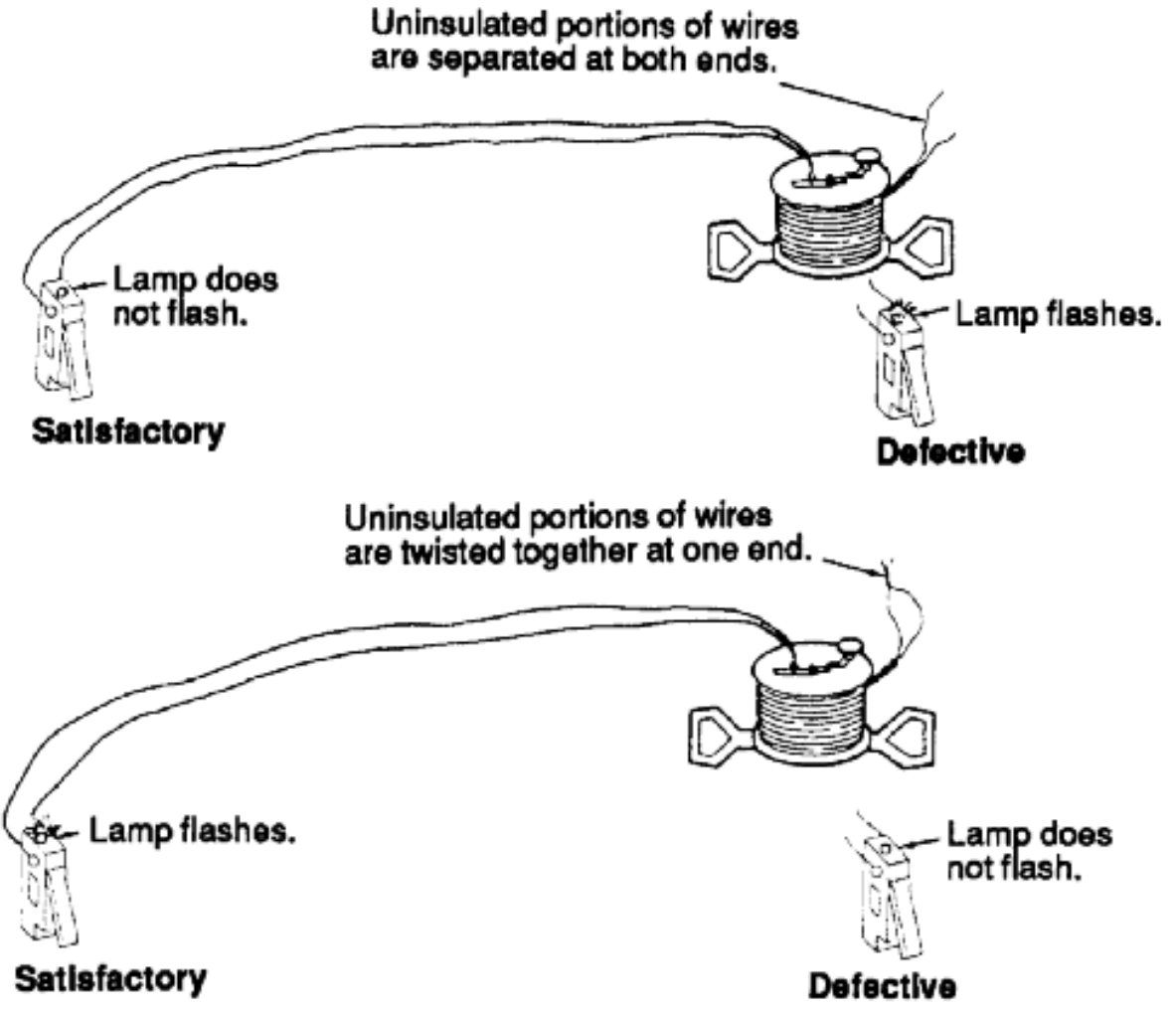


Figure 2-6. Testing firing wire on the reel

(b) Shunt the wires atone end and connect the leads from the other end to the posts of the M51 test set. Squeeze the test-set handle. The indicator lamp should flash. If it does not, the lamp's failure to light indicates a break in the firing wire (Figure 2-6).

NOTE: Use at least three 180-degree turns to shunt wires.

(c) Shunt both ends of the firing wire after testing.

(4) Laying Out Firing Wire.

(a) After locating a firing position a safe distance away from the charges (paragraph 6-7, page 6-6), lay out the firing

wire between the charges and the firing position. More than one reel of wire may be necessary.

(b) Do not allow vehicles to drive over or personnel to walk on firing wire. Always bury firing wire or lay it flat on the ground.

(c) Keep the firing wire as short as possible. Avoid creating any loops in the wire (lay it in as straight a line as possible). Cut the wire to length. Do not connect it to a blasting machine through the unused portion of wire on the reel.

(5) Retesting Firing Wire.

(a) Perform the open- and short-circuit tests again. The process of unreeling the wire may have separated broken wires not found when the wire was tested on the reel.

(b) Continually guard the firing position from this point on. Do this to ensure that no one tampers with the wires or fires the charges prematurely.

(c) Use hand signals to indicate the test results. Hand signals are necessary because of the distance involved between the charges and the firing position. The man testing the wire also can give these signals directly to the soldier at the opposite end of the wire or, if they cannot see each other, through intermediate positions or over the radio. The tester indicates to his assistant that he wants the far end of the firing wire unshunted by extending both arms straight out at shoulder height.

After unshunting the firing wire, the assistant at the far end of the wire repeats the signal, indicating to the tester that his end is unshunted. When the tester wants the far end of the firing wire shunted, he signals to his assistant by clasping his hands together and extending his arms over his head, elbows bent, forming a diamond shape. After shunting the firing wire, the assistant repeats the signal, indicating to the tester that his wire is shunted.

(d) Shunt both ends of the firing wire after the tests are complete.

(6) Testing Electric Blasting Cap.

(a) Remove the cap from its spool. Place the cap in the palm of your hand, lead wires passing between your thumb and index finger.

(b) Wrap the wire around the palm of your hand twice. Doing this prevents tension on the wires in the cap and prevents the cap from being dropped.

(c) Grasp the wire spool with your free hand and unreel the wire, letting the wire pass between your fingers as you turn the spool. Completely unreel the cap wires from the cardboard spool. Avoid allowing the wires to slip offends of the cardboard spool, since this will cause excessive twists and kinks in the wires and prevent the wires from separating properly.

(d) Place the blasting cap under a sandbag or helmet while extending the wires to their full length.

(e) Test blasting caps away from all other personnel. Keep your back to the blasting cap when testing it.

(f) Remove the short-circuit shunt from the lead wires.

(g) Hold or attach one lead wire to one of the M51‘s binding posts. Hold or attach the second lead wire to the other binding post and squeeze the test-set handle. The blasting cap is good if the indicator lamp flashes. If the lamp does not flash, the cap is defective; do not use it.

(h) Always keep the cap wires shunted when not testing them.

(7) Connecting a Series Circuit. When two or more blasting caps are required for a demolition operation. you may use one of the series circuits illustrated in Figure 2-7.

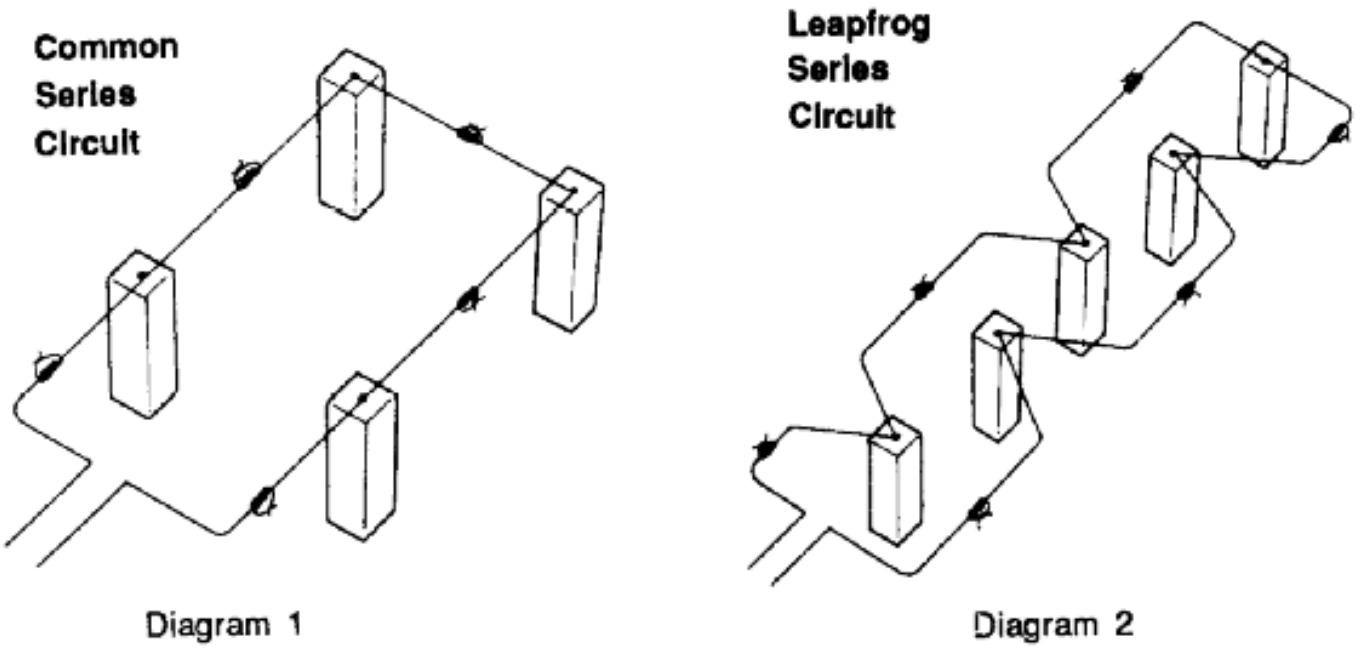


Figure 2-7. Series circuit

Use the following procedure:

(a) Test all blasting caps separately before connecting them in a circuit.

(b) Join blasting cap wires together using the Western Union pigtail splice (Figure 2-8). Protect all joints in the circuit with electrical insulation tape. Do not use the cardboard spool that comes with the blasting cap to insulate these connections.

(c) Test the entire circuit. After the series is completed, connect the two free blasting cap wires to the M51 test set. The indicator lamp should flash to indicate a good circuit. If the lamp does not flash, check your connections and blasting caps again.

(d) After testing the cap circuit, shunt the two free blasting cap wires until you are ready to connect them to the firing wire.

(8) Connecting the Firing Wire.

(a) Connect the free leads of blasting caps to the firing wire before priming the charges or taping a blasting cap to a detonating-cord ring main.

(b) Use a Western Union pigtail splice to connect the firing wire to the blasting cap wires.

(c) Insulate the connections with tape. Never use the cardboard spool that comes with the blasting cap to insulate this connection. The firing wire is likely to break when bent to fit into the spool.

(9) Testing the Entire Firing Circuit. Before priming the charges or connecting blasting caps to ring mains, test the circuit from the firing point. Use the following procedure:

(a) Ensure the blasting caps are under protective sandbags while performing this test.

(b) Connect the ends of the firing wire to the M51 test set. Squeeze the firing handle. The indicator lamp should flash, indicating a proper circuit.

(c) Shunt the ends of the firing wire.

WARNING

Do not prime charges or connect electric blasting caps to detonating cord until all other steps of the preparation sequence have been completed.

(10) Priming the Charges. Prime the charges and return to the firing point. This is the last step prior to actually returning to the firing point and firing the circuit.

WARNING

Prime charges when there is a minimum of personnel on site.

c. Circuit Initiation. At this point the initiation set is complete. Do not connect the blasting machine until all personnel are accounted for and the charge is ready to fire. When all personnel are clear, install the blasting machine

and initiate the demolition. Chapter 6 (page 6-9) covers procedures for electric misfires.

d. Splicing Electric Wires.

(1) Preparation. Strip the insulating material from the end of insulated wires before splicing.

Remove approximately 1 ½ inches of insulation from the end of each wire (Figure 2-8, diagram 1).

Also remove any coating on the wire, such as enamel, by carefully scraping the wire with the back of a knife blade or other suitable tool. Do not nick, cut, or weaken the bare wire. Twist multiple-strand wires lightly after scraping.

(2) Method. Use the Western Union pigtail splice (Figure 2-8, page 2-8) to splice two wires.

Splice two pairs of wires in the same way as the two-wire splice (Figure 2-9). Use the following procedure:

(a) Protect the splices from tension damage by tying the ends in an overhand or square knot (tension knot), allowing sufficient length for each splice (Figure 2-8, diagram 2, page 2-8).

(b) Make three wraps with each wire (Figure 2-8, diagram 3, page 2-8).

(c) Twist the ends together with three turns (Figure 2-8, diagram 4, page 2-8).

(d) Flatten the splice, but not so far that the wire crimps itself and breaks (Figure 2-8, diagram 5, page 2-8).

(3) Precautions. A short circuit may occur at a splice if you do not practice some caution. For example, when you splice pairs of wires, stagger the splices and place a tie between them (Figure 2-9, diagram 1). Another method of preventing a short circuit in a splice is using the alternate method (Figure 2-9, diagram 2). In the alternate method, separate the splices rather than stagger them. Insulate the splices from the ground or other conductors by wrapping them with friction tape or other electric insulating tape. Always insulate splices.

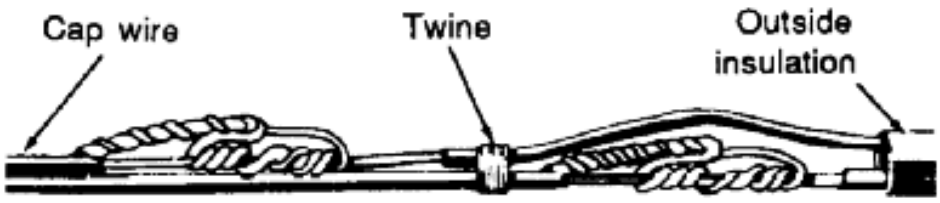


Diagram 1

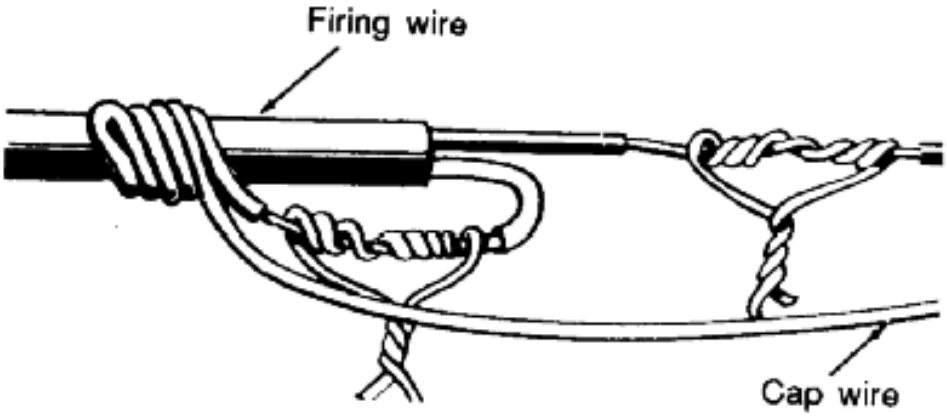


Diagram 2

Figure 2-9. Two-wire splice

e. Series Circuits.

(1) Common. Use this circuit to connect two or more electric blasting caps to a single blasting machine (Figure 2-7, diagram 1, page 2-8). Prepare a common series circuit by connecting one blasting cap to another until only two end wires are free. Shunt the two end wires until you are ready to proceed with the next step. Connect the free ends of the cap lead wires to the ends of the firing wire. Use connecting wires (usually annunciator wire) when the distance between blasting caps is greater than the length of the usual cap lead wires.

(2) Leapfrog. The leapfrog method of connecting caps in a series is useful for firing any long line of charges (Figure 2-7, diagram 2, page 2-8). This method is performed by starting at one end of a row of charges and priming alternate charges to the opposite end and then priming the remaining charges on the return leg of the series. This method eliminates the necessity for a long return lead from the far end of the line of charges. Appendix E has additional information on series circuits.

There is seldom a need for this type of circuit, since detonating cord, when combined with a single blasting cap, will fire multiple charges.

Section II. Priming Systems

2-3. Methods. The three methods of priming charges are non-electric, electric, and detonating-cord.

Non-electric and electric priming involves directly inserting

blasting caps into the charges. Use the direct-insertion method only when employing shaped charges. Detonating-cord priming is the preferred method for priming all other charges since it involves fewer blasting caps, makes priming and misfire investigation safer, and allows charges to be primed at State of Readiness 1 (safe) when in place on a reserved demolition.

NOTE: You can crimp non-electric blasting caps to detonating cord as well as time fuse. This capability permits simultaneous firing of multiple charges primed with a blasting cap.

2-4. Priming TNT Demolition Blocks.

a. Non-electric. TNT blocks have threaded cap wells. Use priming adapters, if available, to secure non-electric blasting caps and timed blasting fuses to TNT blocks with threaded cap wells (Figure 2-10). When priming adapters are not available, prime TNT blocks with threaded cap wells as follows:

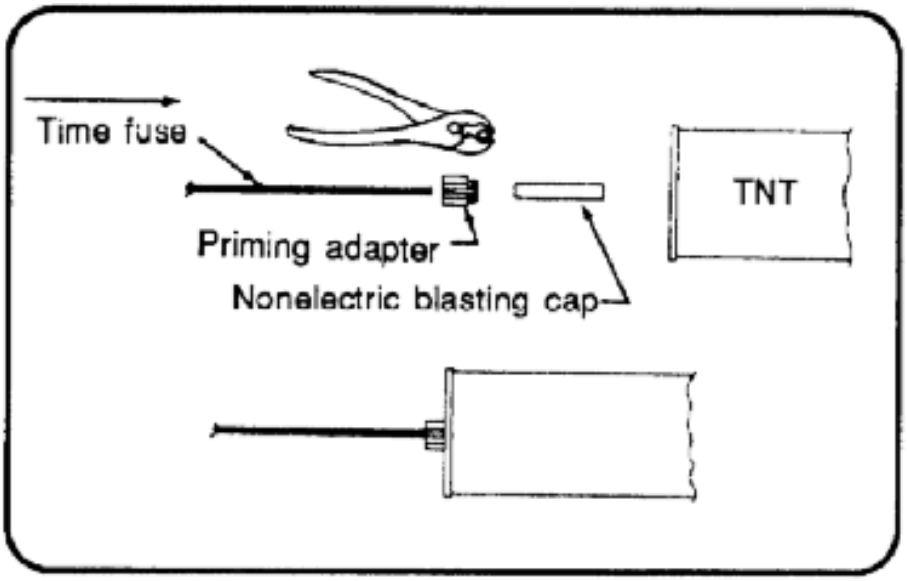
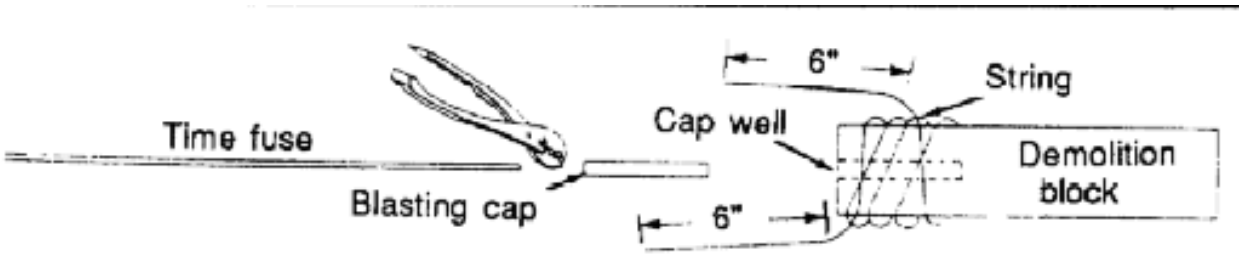


Figure 2-10. Nonelectric priming with adapter

(1) Wrap a string tightly around the block of TNT and tie it securely, leaving approximately 6 inches of loose string on each end (Figure 2-11).

(2) Insert a blasting cap with the fuse attached into the cap well.

(3) Tie the loose ends of the string around the fuse to prevent the blasting cap from being separated from the block. Adhesive tape can also effectively secure blasting caps in charges.



NOTE: Do *not* tie string so tightly that the powder train is broken in the fuse. Electrical or friction tape may be substituted for string if necessary.

Figure 2-11. Nonelectric priming without adapter

b. Electric.

(1) With Priming Adapter. Use the following procedure for priming TNT block, using the priming adapter:

(a) Prepare the electric initiation set before priming.

(b) Pass the lead wires through the slot of the adapter, and pull the cap into place in the adapter (Figure 2-12). Ensure the blasting cap protrudes from the threaded end of the adapter.

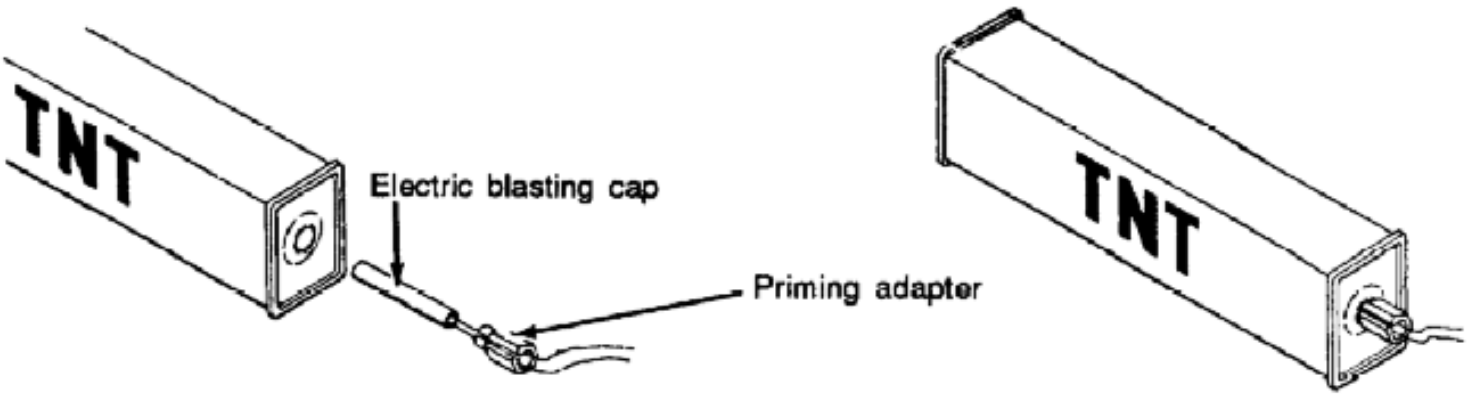


Figure 2-12. Electric priming with adapter

(c) Insert the blasting cap into the threaded cap well of the TNT block and screw the adapter into place.

(2) Without Priming Adapter. If a priming adapter is not available, use the following procedure:

(a) Prepare the electric initiation set before priming.

(b) Insert the electric blasting cap into the cap well. Tie the lead wires around the block, using two half hitches or a girth hitch (Figure 2- 13). Allow some slack in the wires between the blasting cap and the tie to prevent any tension on the blasting-cap lead wires.

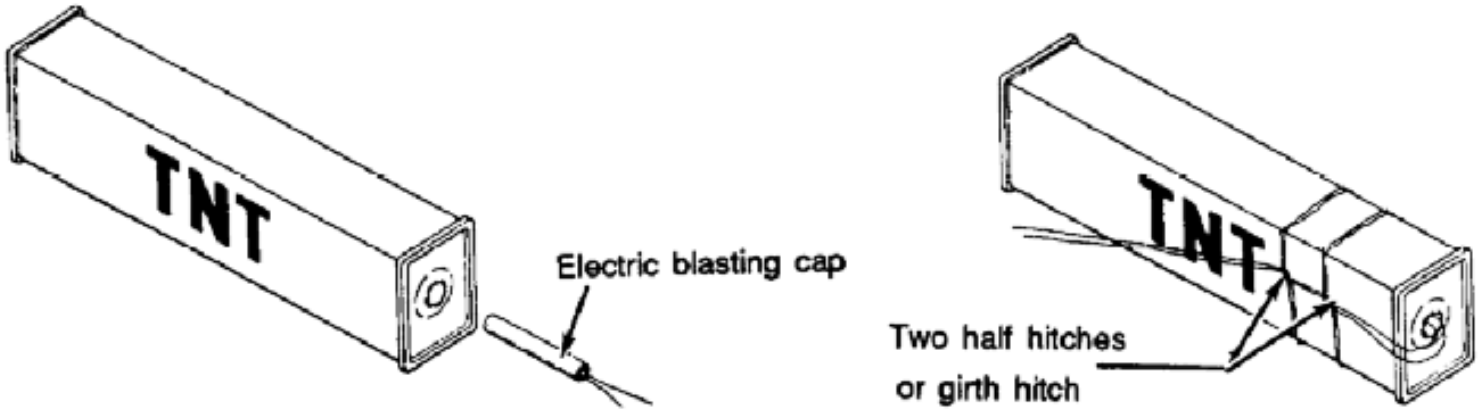


Figure 2-13. Electric priming without adapter

c. Detonating Cord. Use the following methods to prime TNT blocks with detonating cord:

NOTE: A 6-inch length of detonating cord equals the power output of a blasting cap. However, detonating cord will not detonate explosives as reliably as a blasting cap because its power is not as concentrated. Therefore, always use several turns or a knot of detonating cord for priming charges.

(1) Method 1 (Figure 2-14). Lay one end (l-foot length) of detonating cord at an angle across the explosive. Then, wrap the running end around the block three turns, laying the wraps over the standing end. On the fourth wrap, slip the running end under all wraps, parallel to the standing end and draw the wraps tight. Doing this forms a clove hitch with two extra turns.

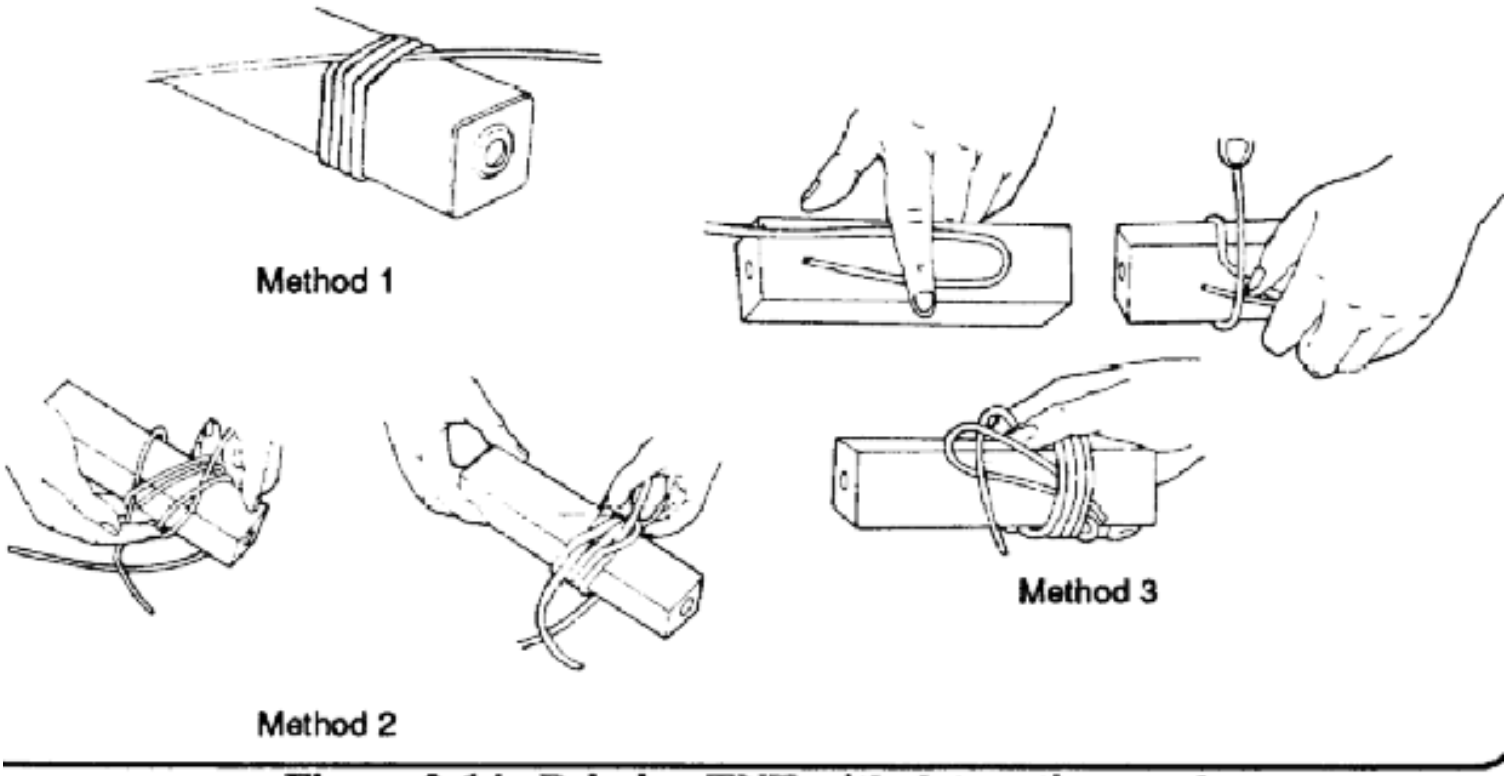


Figure 2-14. Priming TNT with detonating cord

(2) Method 2 (Figure 2-14). Tie the detonating cord around the explosive block with a clove hitch and two extra turns. Fit the cord snugly against the block, and push the loops close together.

(3) Method 3 (Figure 2-14). Place a loop of detonating cordon the explosive, leaving sufficient length on the end to make four turns around the block and loop with the remaining end of the detonating cord. When starting the first wrap, ensure that you immediately cross over the standing end of the loop, working your way to the closed end of the loop. Pass the free end of the detonating cord through the loop and pull it tight. This forms a knot around the outside of the block.

2-5. Priming M112 (C4) Demolition Blocks.

a. Non-electric and Electric. C4 blocks do not have a cap well; therefore, you will have to make one. Use the following procedure:

(1) With the M2 crimpers or other non-sparking tool, make a hole in the end or on the side (at the midpoint) large enough to hold the blasting cap.

(2) Insert the blasting cap into the hole or cut. If the blasting cap does not fit the hole or cut, do not force the cap, make the hole larger.

(3) Anchor the blasting cap in the block by gently squeezing the plastic explosive around the blasting cap.

b. Detonating Cord. To prime plastic explosive with detonating cord, use the following procedure:

(1) Form either a Uli knot, double overhand knot, or triple roll hot as shown in Figure 2-15.

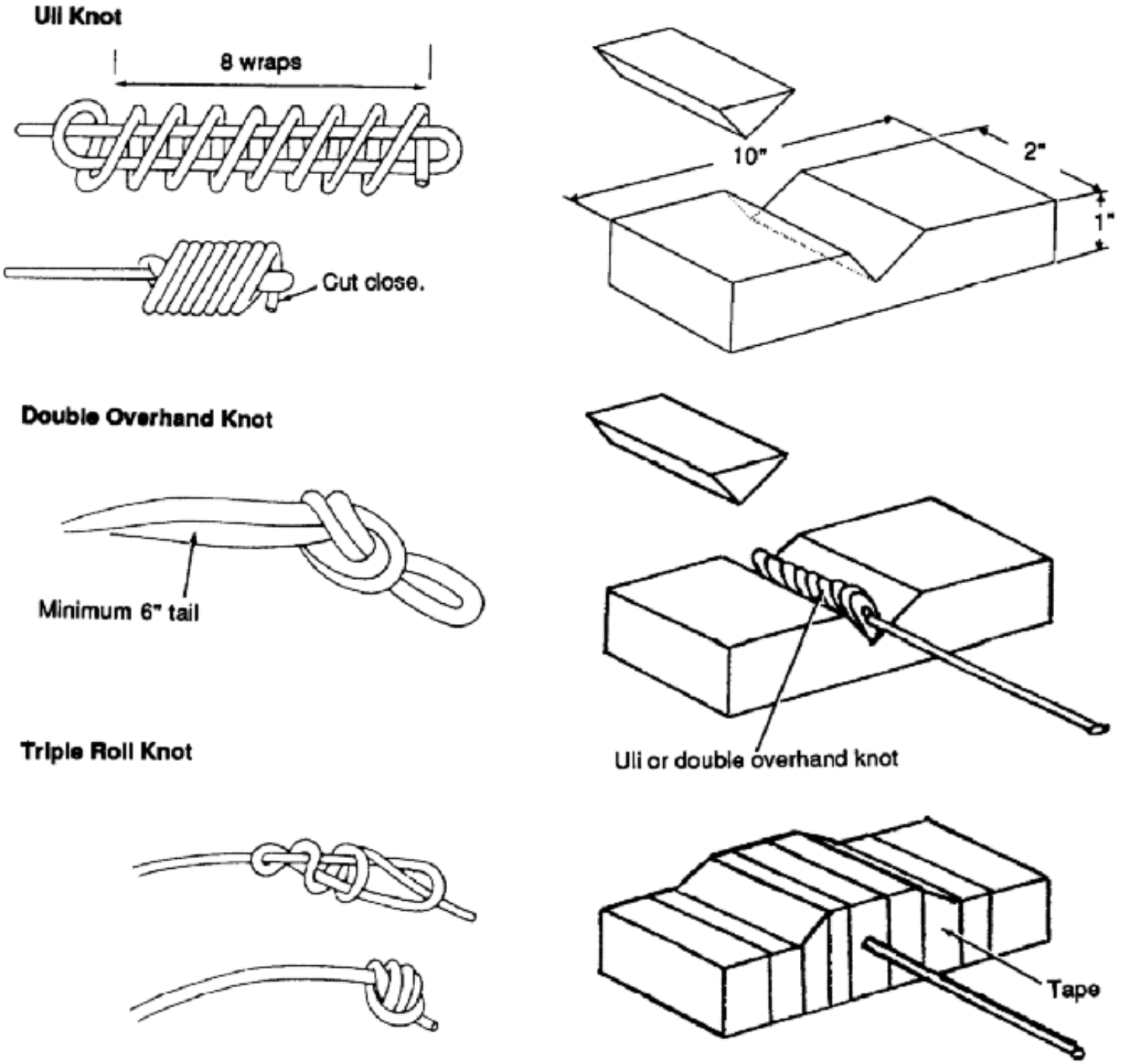


Figure 2-15. Priming plastic explosives with detonating cord

(2) Cut a notch out of the explosive, large enough to insert the knot you formed.

WARNING

Use a sharp knife on a non-sparking surface to cut explosives.

(3) Place the knot in the cut.

(4) Use the explosive you removed from the notch to cover the knot. Ensure there is at least ½ inch of explosive on all sides of the knot.

(5) Strengthen the primed area by wrapping it with tape.

NOTE: It is not recommended that plastic explosives be primed by wrapping them with detonating cord, since insufficient wraps will not properly detonate the explosive charge.

2-6. Priming M118 and M186 Demolition Charges.

a. Non-electric and Electric. Use one of the following methods to prime M118 and M186 demolition charges:

(1) Method 1 (Figure 2-16, page 2- 16). Attach an M8 blasting cap holder to the end or side of the sheet explosive. Insert an electric or a non-electric blasting cap into the holder until the end of the cap presses against the sheet explosive. The M8 blasting cap holder has three slanted, protruding teeth which prevent the clip from withdrawing from the explosive. Two dimpled spring arms firmly hold the blasting cap in the M8 holder.

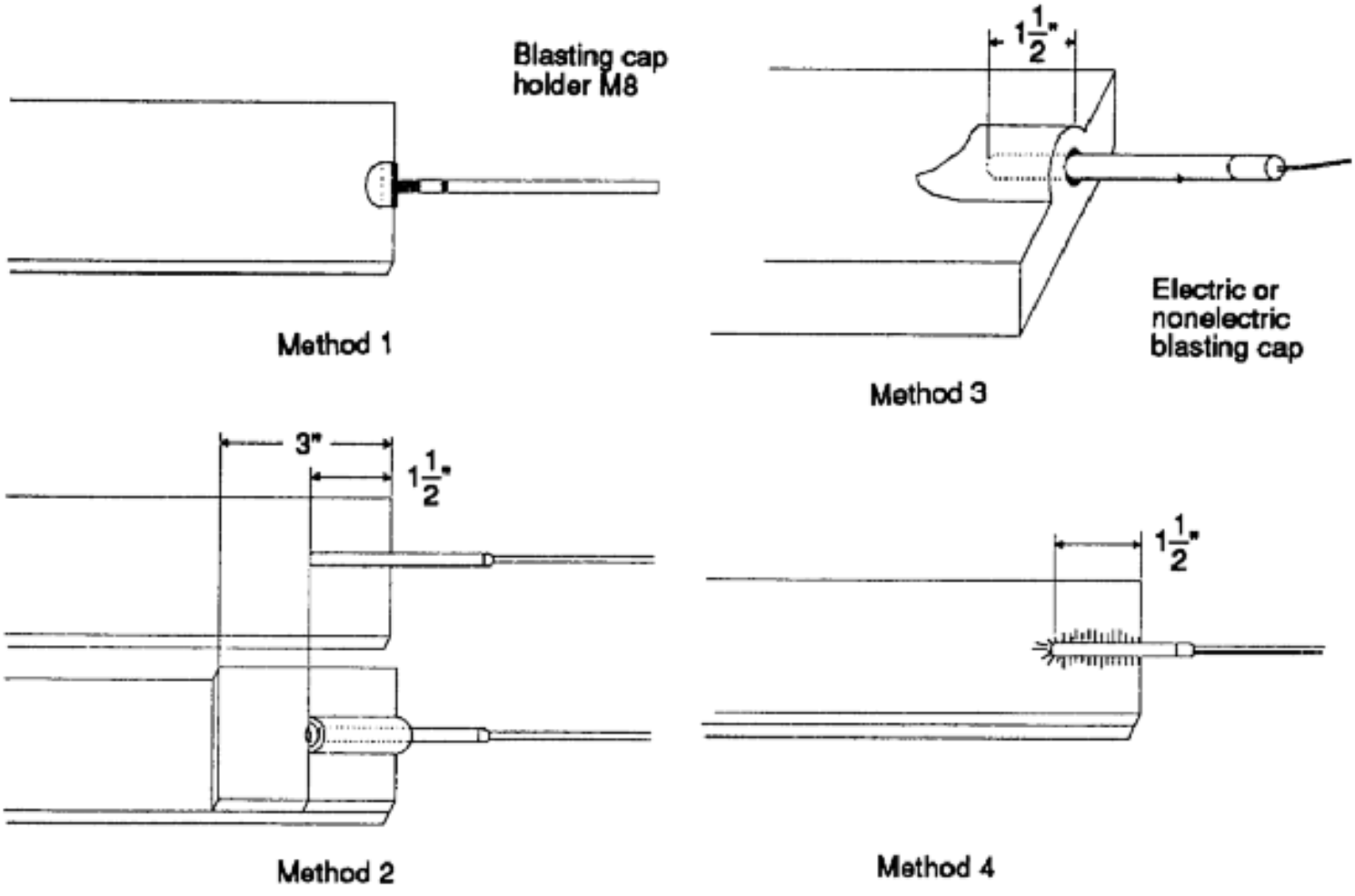


Figure 2-16. Priming sheet explosives

(2) Method 2 (Figure 2-16, page 2-16). Cut a notch in the sheet explosive (approximately 1½ inches long and ¼ inch wide). Insert the blasting cap to the limit of the notch. Secure the blasting cap with a strip of sheet explosive.

(3) Method 3 (Figure 2-16, page 2-16). Place 1½ inches of the blasting capon top of the sheet explosive and secure it with a strip of sheet explosive (at least 3 by 3 inches).

(4) Method 4 (Figure 2-16, page 2- 16). Insert the end of the blasting cap 1½ inches between two sheets of explosive.

b. Detonating Cord. Sheet explosives also can be primed

with detonating cord using a Uli knot, double overhand knot, or triple roll knot. Insert the knot between two sheets of explosive or place the knot on top of the sheet explosive and secure it with a small strip of sheet explosive. The knot must be covered on all sides with at least ½ inch of explosive. 2-7. Priming Dynamite. Prime dynamite at either end or side. Choose the method that will prevent damage to the primer during placement.

a. Non-electric. There are three methods for priming dynamite non-electrically:

(1) End-Priming Method (Figure 2-17).

(a) Using the M2 crimpers, make a cap well in the end of the dynamite cartridge.

(b) Insert a fused blasting cap into the cap well.

(c) Tie the cap and fuse securely in the cartridge with a string.

(2) Weatherproof, End-Priming Method (Figure 2-17).

(a) Unfold the wrapping at the folded end of the dynamite cartridge.

(b) Using the M2 crimpers, make a cap well in the exposed dynamite.

(c) Insert a fused blasting cap into the cap well.

(d) Close the wrapping around the fuse and fasten the

wrapping securely with a string or tape.

(e) Apply a weatherproof sealing compound to the tie.

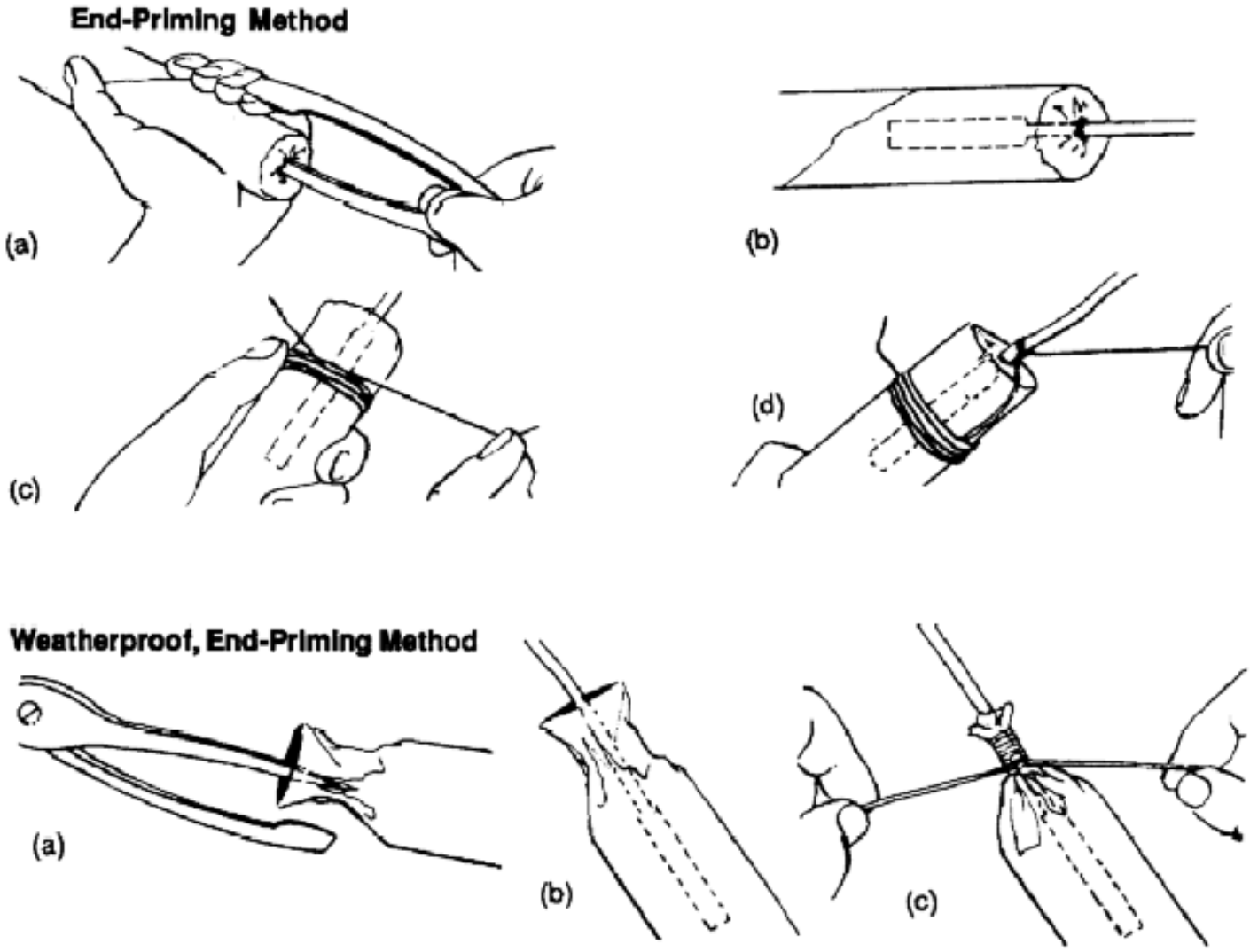


Figure 2-17. Nonelectric end priming of dynamite

(3) Side-Priming Method (Figure 2-18, page 2-18).

(a) Using the M2 crimpers, make a cap well (approximately 1½ inches long) into the side of the cartridge at one end. Slightly slant the cap well so the blasting cap, when inserted, will be nearly parallel to the side of the cartridge and the explosive end of the cap will be at a point nearest the middle of the cartridge.

(b) Insert a fused blasting cap into the cap well.

(c) Tie a string securely around the fuse. Then, wrap the string tightly around the cartridge, making two or three turns before tying it.

(d) Weatherproof the primed cartridge by wrapping a string closely around the cartridge, extending it an inch or so on each side of the hole to cover it completely. Cover the string with a weatherproof sealing compound.

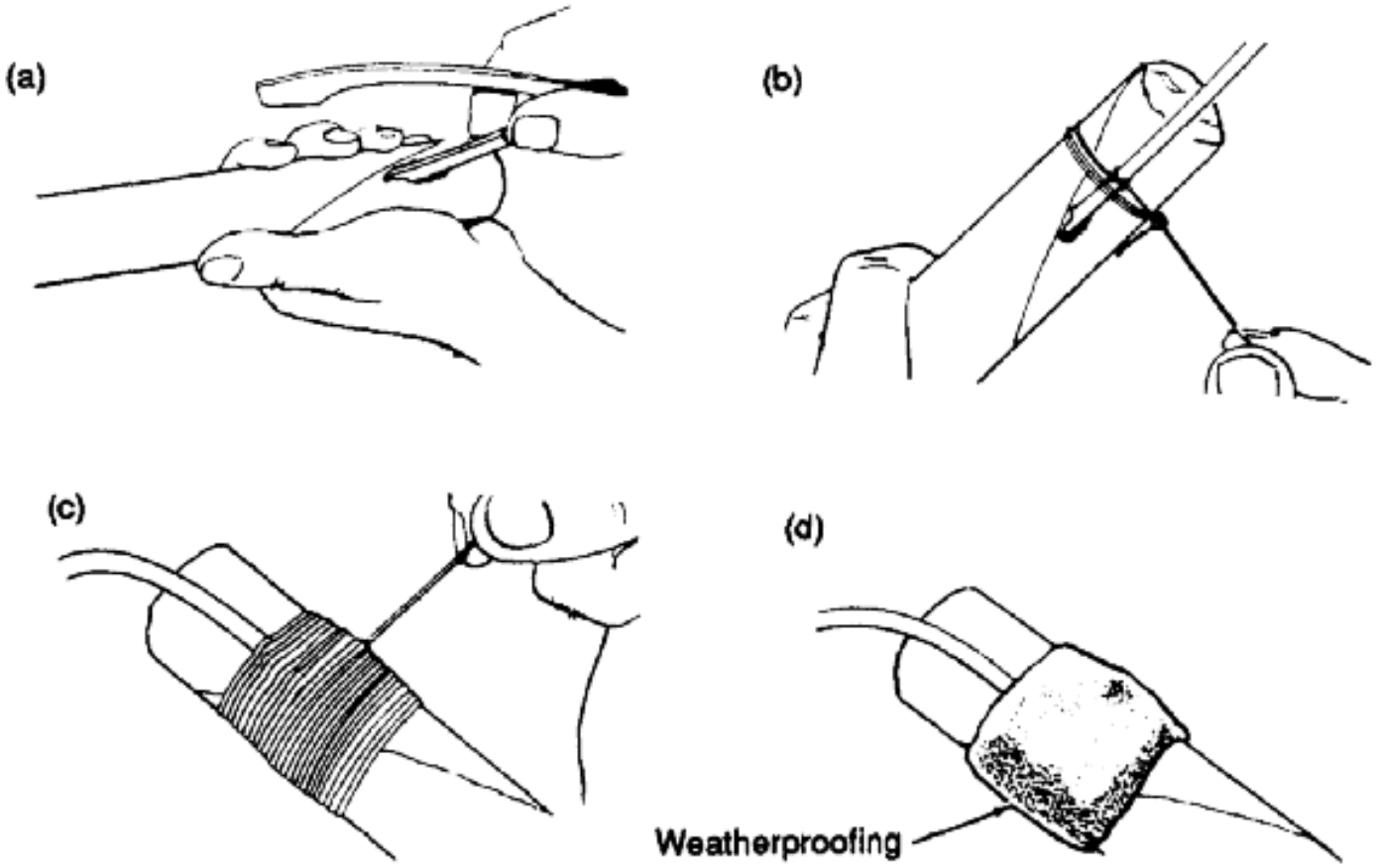


Figure 2-18. Nonelectric side priming of dynamite

b. Electric. Use the following method for priming with electric blasting caps:

(1) End-Priming Method (Figure 2-19).

(a) Using the M2 crimpers, make a cap well in the end of the cartridge.

(b) Using the M2 crimpers, insert an electric blasting cap into the cap well.

(c) Tie the lead wires around the cartridge with two half hitches, a string, or tape.

(2) Side-Riming Method (Figure 2-19).

(a) Using the M2 crimpers, make a cap well (approximately 1½ inches long) into the side of the cartridge at one end. Slightly slant the cap well so the blasting cap, when inserted, will be nearly parallel to the side of the cartridge and the explosive end of the cap will be at a point nearest the middle of the cartridge.

(b) Using the M2 crimpers, insert an electric blasting cap into the cap well.

(c) Tie the lead wire around the cartridge with two half hitches, a string, or tape.

c. Detonating Cord. You also can use detonating cord to prime dynamite. Using the M2 crimpers, start approximately 1 inch from either end of the dynamite charge and punch four equally spaced holes through the dynamite cartridge (Figure 2-20). Make sure to rotate the cartridge 180 degrees after punching each hole to keep the holes parallel. Lace detonating cord through the holes in the same direction the holes were punched. Take care not to

pull the loops of the detonating cord too tightly or the dynamite will break. Secure the detonating cord tail by passing it between the detonating cord lace and the dynamite charge.

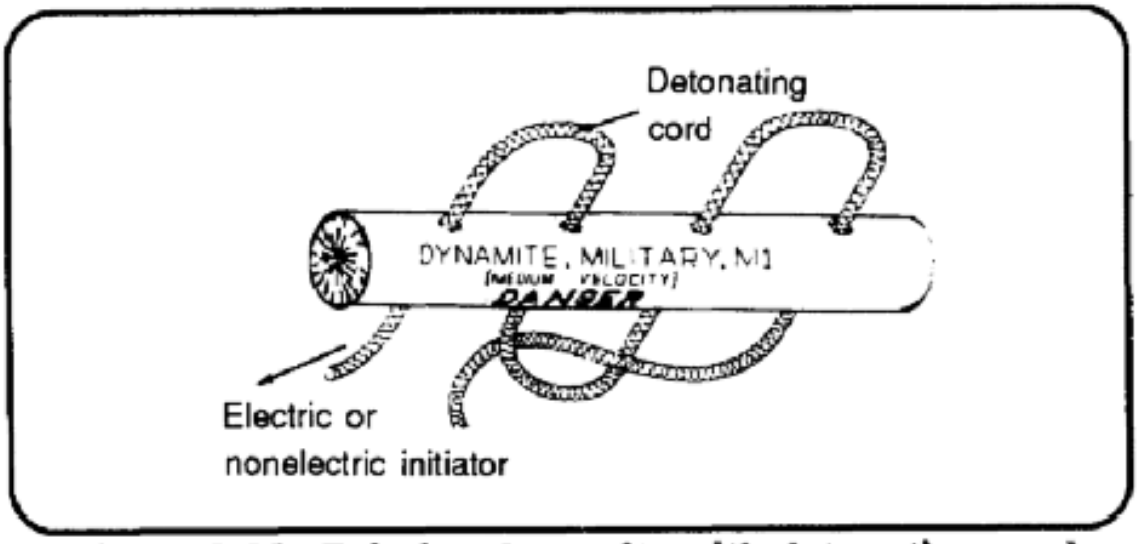
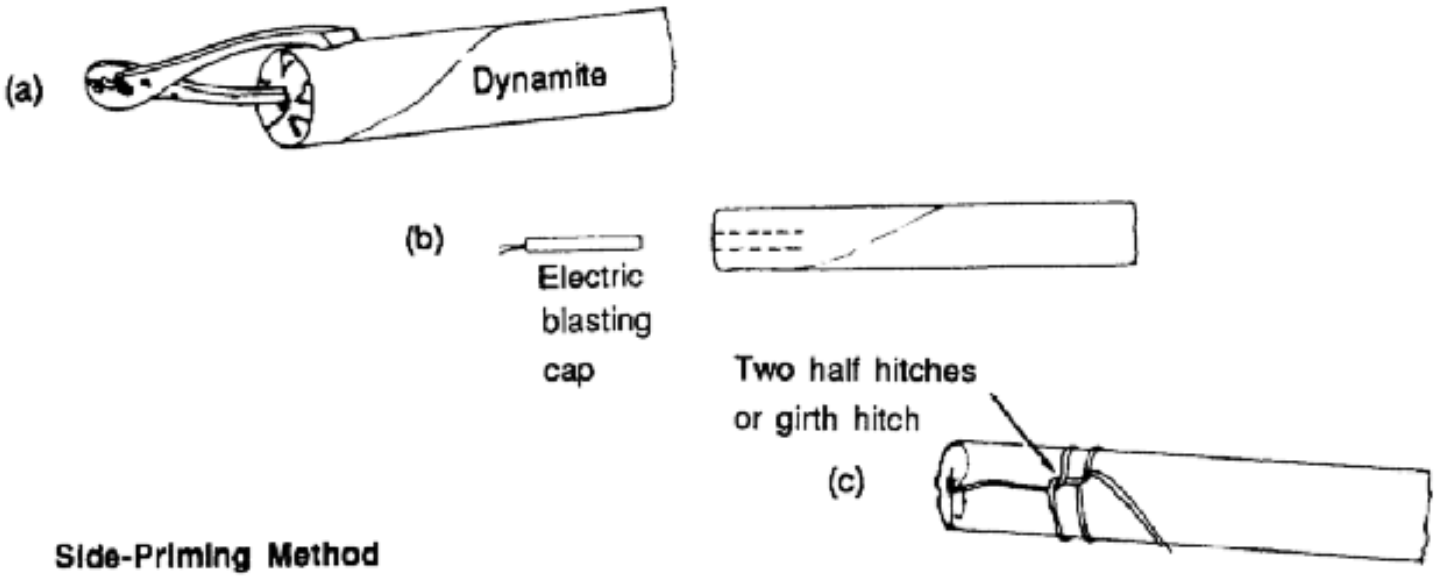
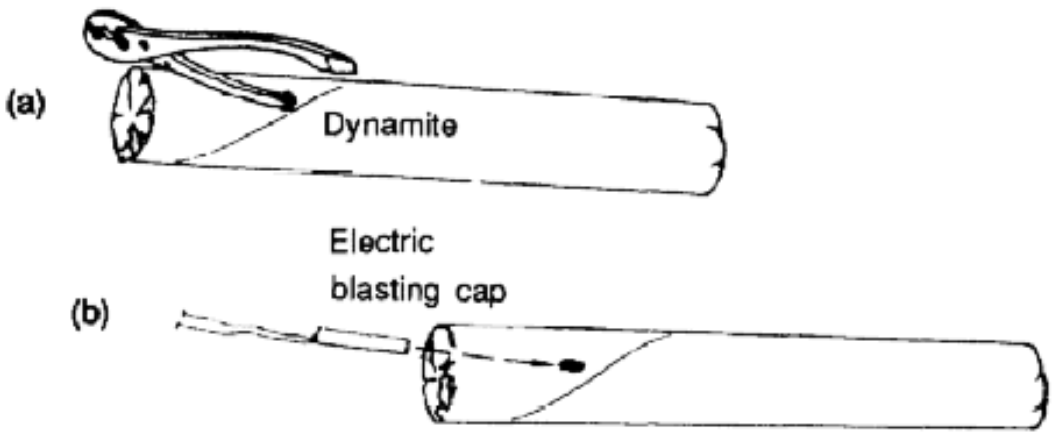


Figure 2-20. Priming dynamite with detonating cord

End-Priming Method



Side-Priming Method



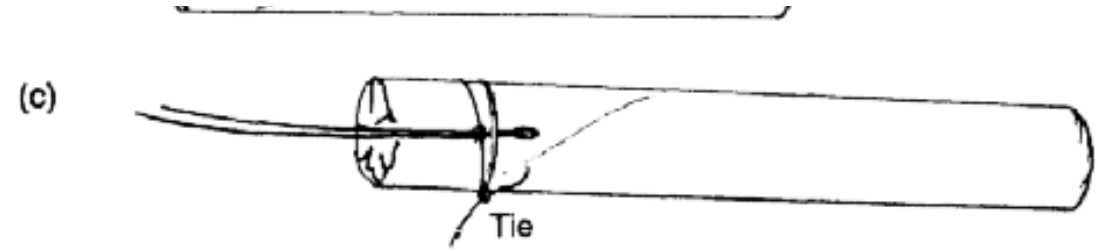


Figure 2-19. Electric priming of dynamite

2-8. Priming 40-Pound, Ammonium-Nitrate Cratering Charges. Because the cratering charge is primarily an underground charge, prime it only with detonating cord. Use dual priming to protect against misfires (Figure 2-21, diagram 2, page 2-20). Use the following procedure:

a. Tie an overhand knot, with a 6-inch overhang, at one end of the length of detonating cord.

b. Pass the opposite end of the detonating cord up through the detonating cord tunnel (Figure 2-21, diagram 1) of the cratering charge.

Ammonium nitrate is hydroscopic. When wet, ammonium nitrate is ineffective. WARNING

Therefore, inspect the metal container for damage or rust. Do not use damaged or rusty charges.

c. When dual priming a single 40-pound cratering charge, use a minimum of one pound of explosive.

Prime a block of TNT or package of C4 with detonating cord (paragraphs 2-4c, page 2-13, and 2-5b, page 2-14, respectively) and tape this charge to the center of the cratering charge (Figure 2-21, diagram 2). The detonating

cord branch lines must be long enough to reach the detonating-cord ring mains after the cratering charge is in the ground. Twelve-foot branch lines should be adequate.

When placing two cratering charges in the same borehole, prime only the detonating cord tunnels of each charge. In this manner, the borehole is dual-primed and extra explosives are not required, as shown in Figure 2-21, diagram 3.

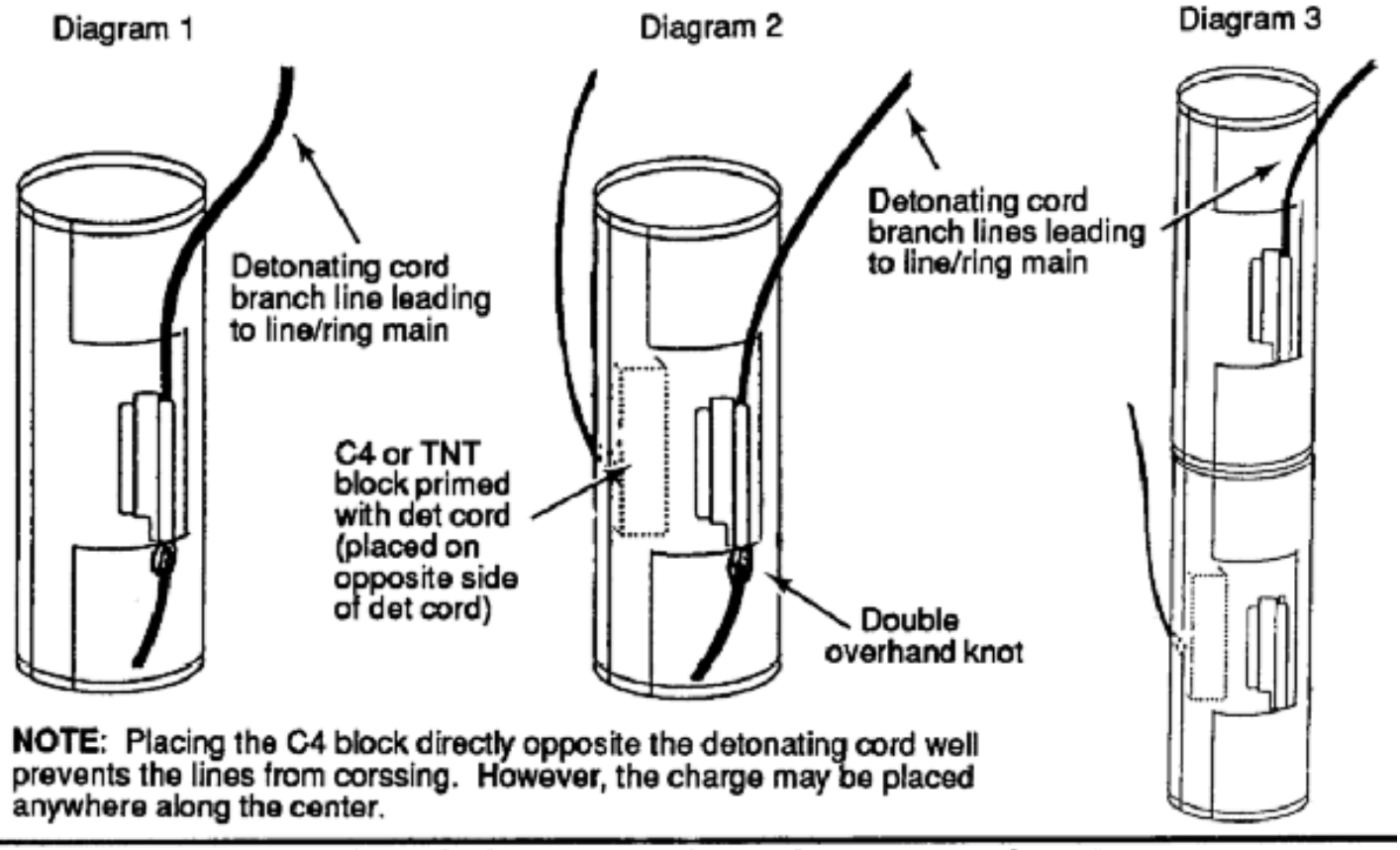


Diagram 1
Diagram 2
Diagram 3
Detonating cord branch line leading to line/ring main
C4 or TNT block primed with det cord (placed on opposite side of det cord)
Detonating cord branch lines leading to line/ring main
Double overhand knot
NOTE: Placing the C4 block directly opposite the detonating cord well prevents the lines from corssing. However, the charge may be placed anywhere along the center.

Figure 2-21. Priming ammonium-nitrate cratering charge

2-9. Priming M2A4 and M3A1 Shaped Charges. The M2A4 and M3A1 are primed only with electric or non-electric blasting caps. These charges have a threaded cap well at the top of the cone.

Prime them with a blasting cap as shown in Figure 2-22. Use a piece of string, cloth, or tape to hold the cap if a

priming adapter is not available. Simultaneously detonate multiple shaped charges to create a line of boreholes for cratering charges by connecting each charge into a detonating-cord ring or line main. Use the following procedure for priming shaped charges:

a. Crimp a non-electric blasting cap to a branch line.

b. Connect the branch line to the ring main.

c. Insert the blasting cap into the blasting cap well of the shaped charge.

d. When detonating multiple shaped charges, make all branch-line connections before priming any shaped charges.

WARNING

Do not dual prime shaped charges. Prime them only with a blasting cap in the blasting cap well.

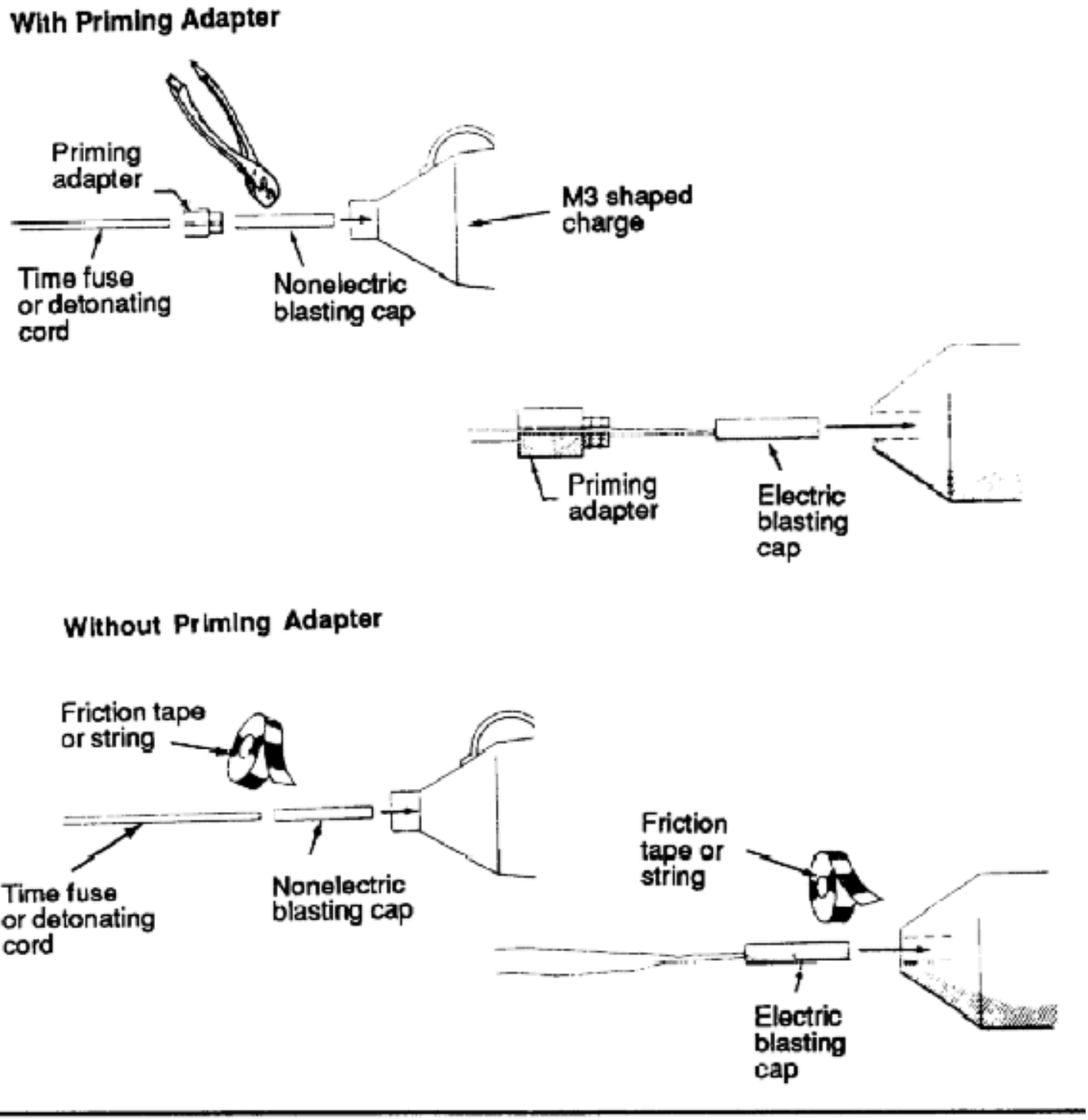


Figure 2-22. Priming shaped charges

2-10. Priming the Bangalore Torpedo.

a. Non-electric. Insert the blasting cap of a non-electric initiation set directly into the cap well of a torpedo section. If a priming adapter is not available, use tape or string to hold the blasting cap in place (Figure 2-23, diagram 1, page 2-22).

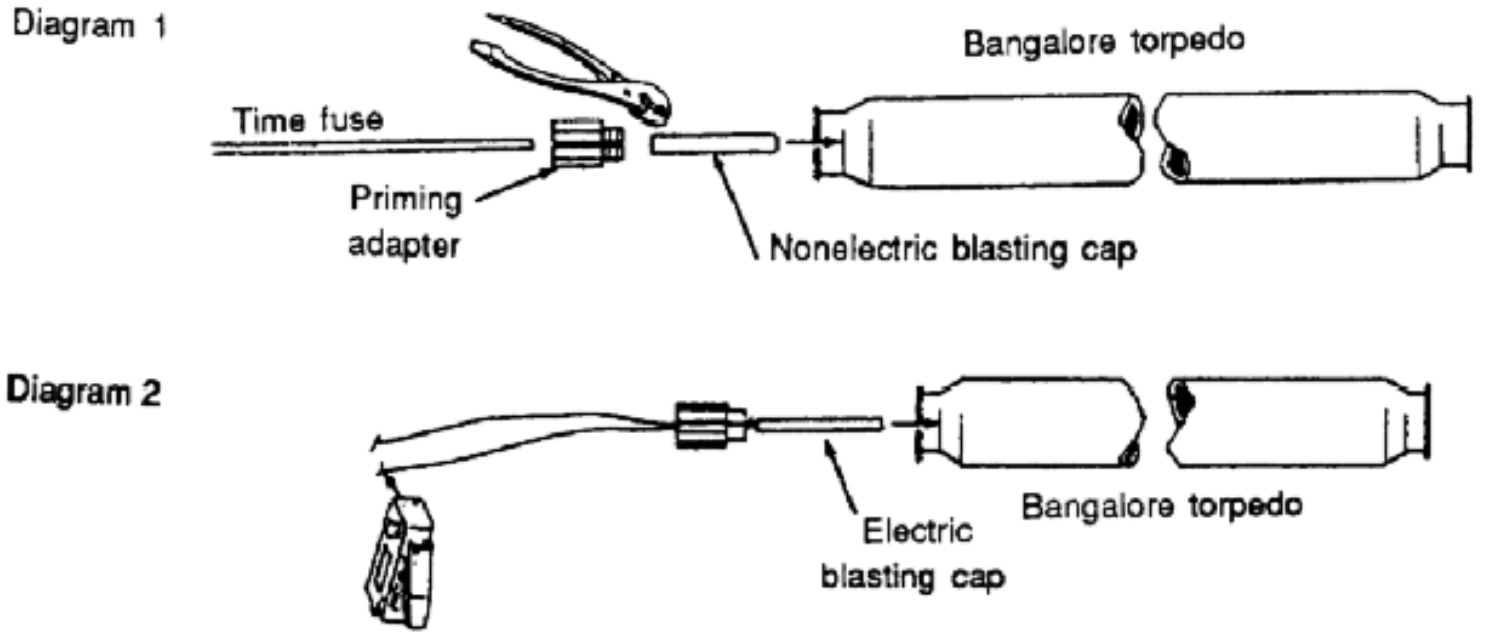


Figure 2-23. Priming a Bangalore torpedo with a blasting cap

b. Electric. Insert the blasting cap of an electric initiation set into the cap well of a torpedo section. If a priming adapter is not available, hold the cap in place by taping or tying (with two half hitches) the lead wires to the end of the torpedo. Allow some slack in the wires between the blasting cap and the tie to prevent tension on the blasting cap leads.

c. Detonating Cord. Prime the torpedo by wrapping detonating cord eight times around the end of the section, just below the bevel (Figure 2-24). After pulling the knot tight, insert the short end of the detonating cord into the cap well and secure it with tape. Never use the short end (tail) of the detonating cord to initiate the torpedo. Initiation must come from the running end of the detonating cord.

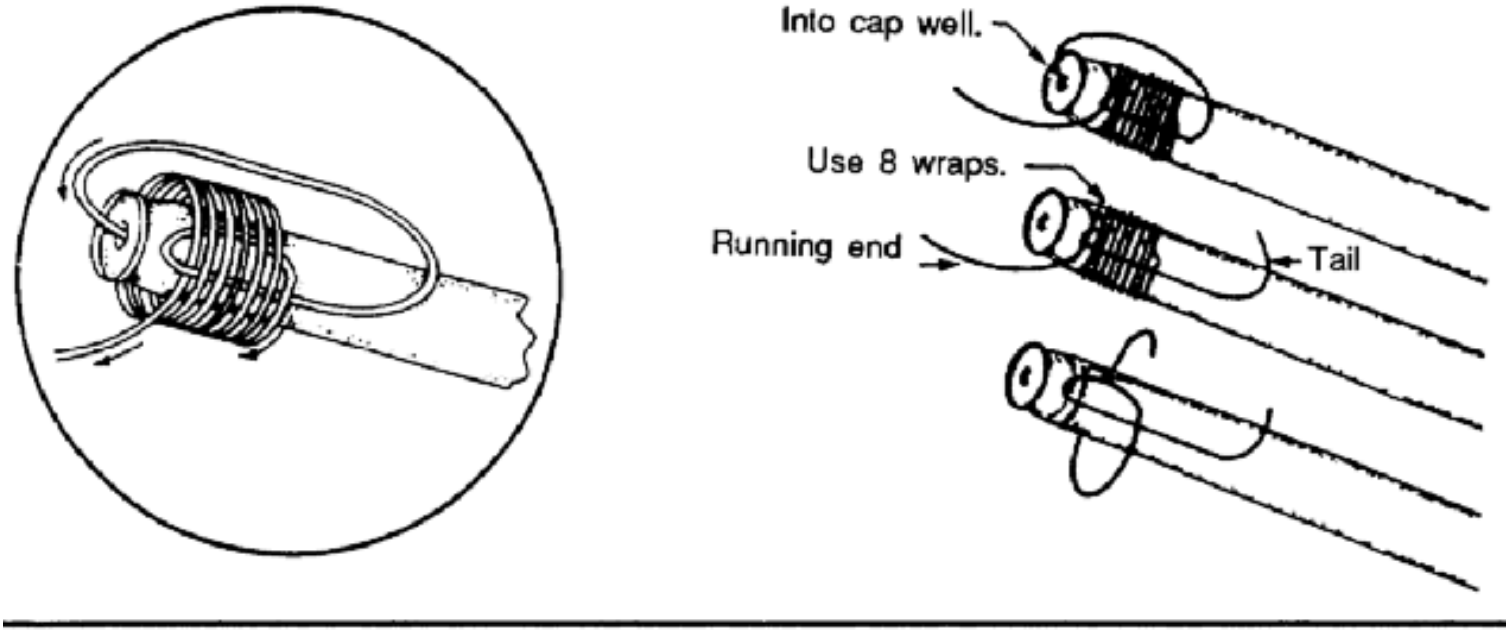


Figure 2-24. Priming a Bangalore torpedo with detonating cord

WARNING

Do not use more than or less than eight wraps to prime the Bangalore torpedo.

Too many wraps will extend the detonating cord past the booster charge housing, possibly causing the torpedo to be cut without detonating. Too few wraps may cause the torpedo to only be crimped, without detonating.

Section III. Firing Systems

2-11. Types of Firing Systems. There are two types of firing systems: single and dual. Chapter 5 covers the tactical applications for these systems.

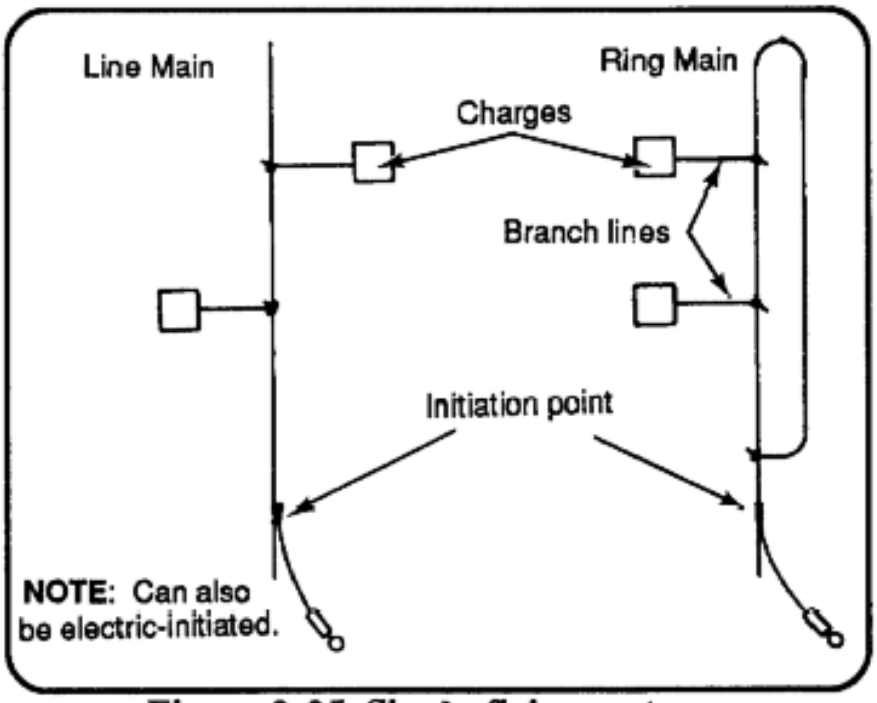


Figure 2-25. Single-firing system (single-initiated, single-fired, single-primed)

a. Single. Figure 2-25 shows a single-firing system Each charge is singly primed with a branch line. The branch line is tied to the line main or ring main. (Tying to the ring main is preferred but construction of a ring main may not be possible because of the amount of detonating cord. The ring main decreases the chances of a misfire should a break or cut occur anywhere within the ring main.) The electric, non-electric, or combination initiation systems are then taped onto the firing system. When using a combination initiation system, the electric initiation system is always the primary means of initiation. When using dual, non-electric initiation systems, the shorter time fuse is the primary initiation system

(Figure 2-26).

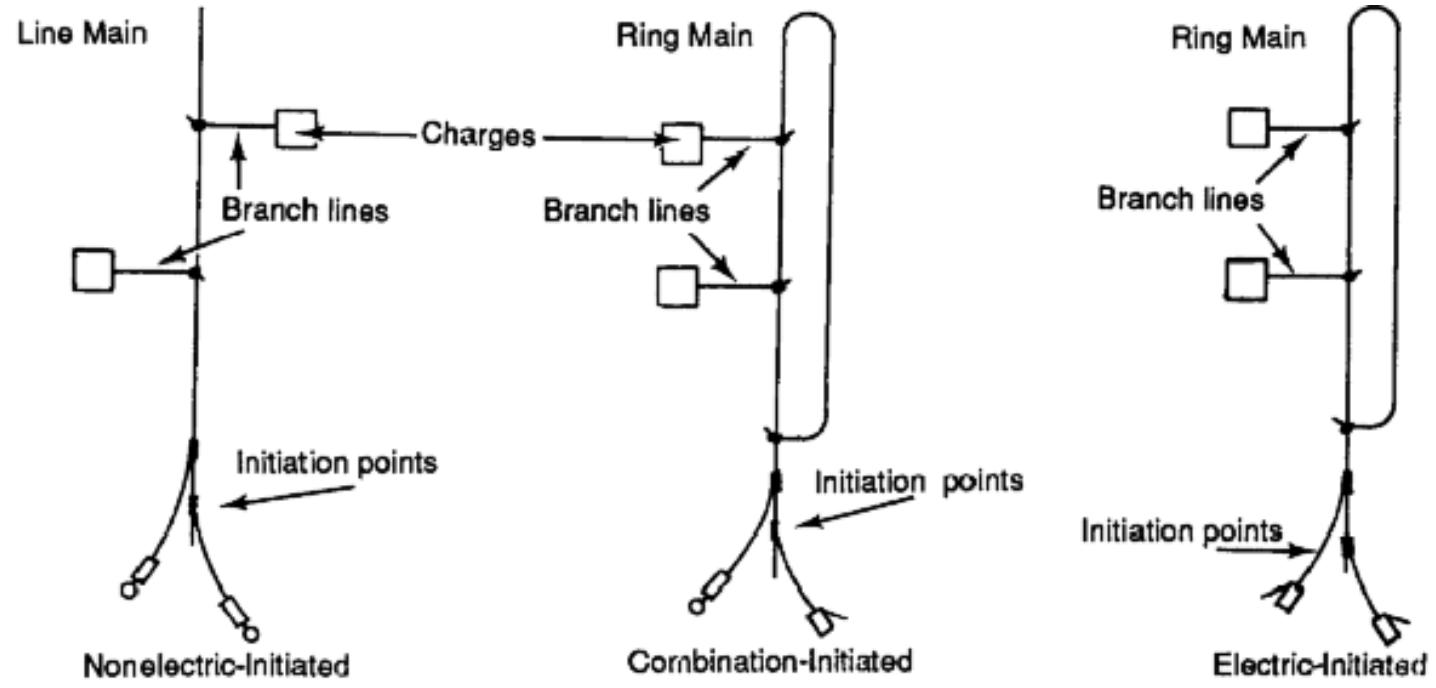


Figure 2-26. Single-firing system (dual-initiated, singled-fired, single-primed)

b. Dual. Figure 2-27 (page 2-24) shows a dual-firing system. Each charge is dual-primed with two branch lines (Figure 2-28, page 2-24). One branch line is tied to one firing system, and the other branch line is tied to an independent firing system. Line mains or ring mains may be used; however, they should not be mixed. To help prevent misfires, use detonating-cord crossovers.

Crossovers are used to tie both firing systems together at the ends. The initiation systems are taped in the primary initiation system goes to one firing system, the secondary goes to the other.

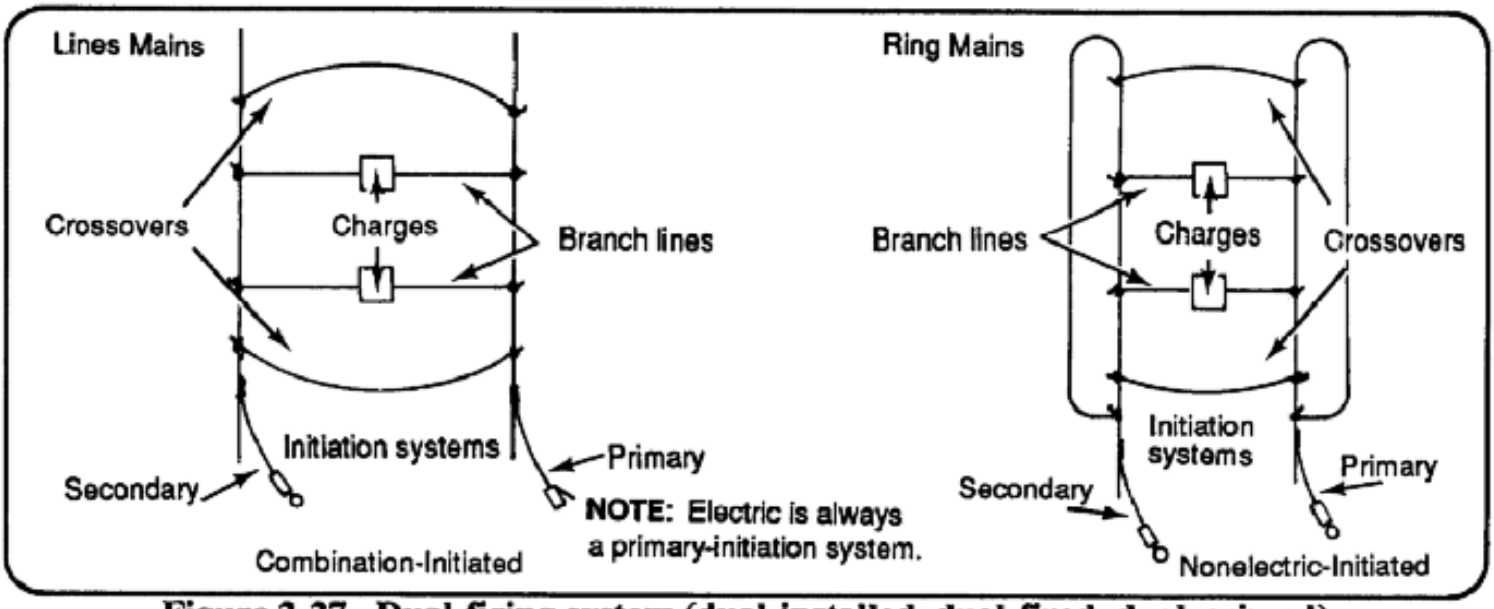


Figure 2-27. Dual-firing system (dual-installed, dual-fired, dual-primed)

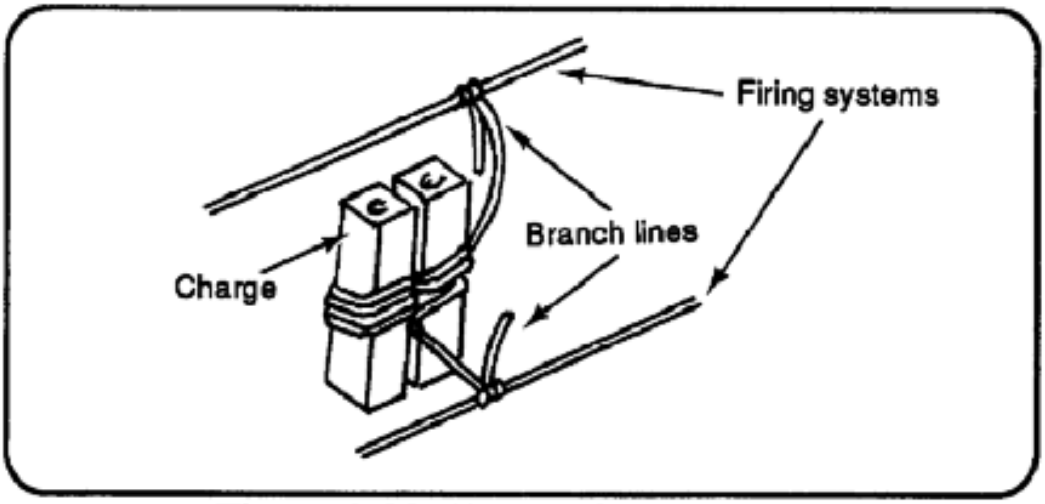


Figure 2-28. Dual-primed charge

Figure 2-29 shows a dual-firing system using horizontal and vertical ring mains. The complexity simultaneous detonation. These will be referred to as horizontal and vertical lines or ring mains.

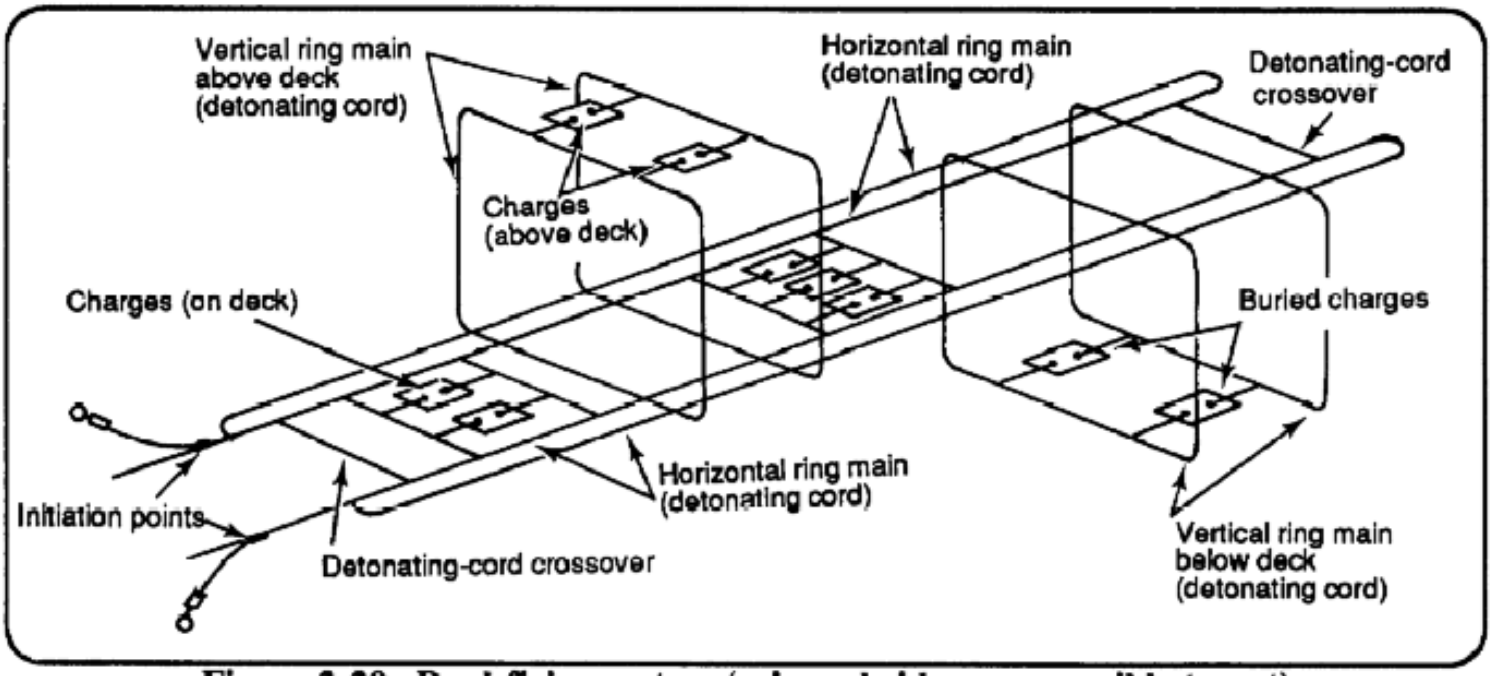


Figure 2-29. Dual-firing system (using a bridge as a possible target)

of a target or obstacle may necessitate using multiple line mains or ring mains for 2-12. Detonating Cord. A firing system uses detonating cord to transmit a shock wave from the initiation set to the explosive charge. Detonating cord is versatile and easy to install. It is useful for underwater, underground, and above-ground blasting because the blasting cap of the initiation set may remain above water or above ground and does not have to be inserted directly into the charge. Detonating-cord firing systems combined with detonating-cord priming are the safest and most efficient ways to conduct military demolition missions. Initiate detonating cord only with non-electric or electric initiation sets.

2-13. Attaching the Blasting Cap. Attach the blasting cap, electric or non-electric, to the detonating cord with tape. You can use string, cloth, or fine wire if tape is not available. Tape the cap securely to a point 6 inches from the end of the detonating cord to overcome moisture

contamination. The tape must not conceal either end of the cap. Taping in this way allows you to inspect the cap in case it misfires. No more than 1/8 inch of the cap needs to be left exposed for inspection (Figure 2-30).

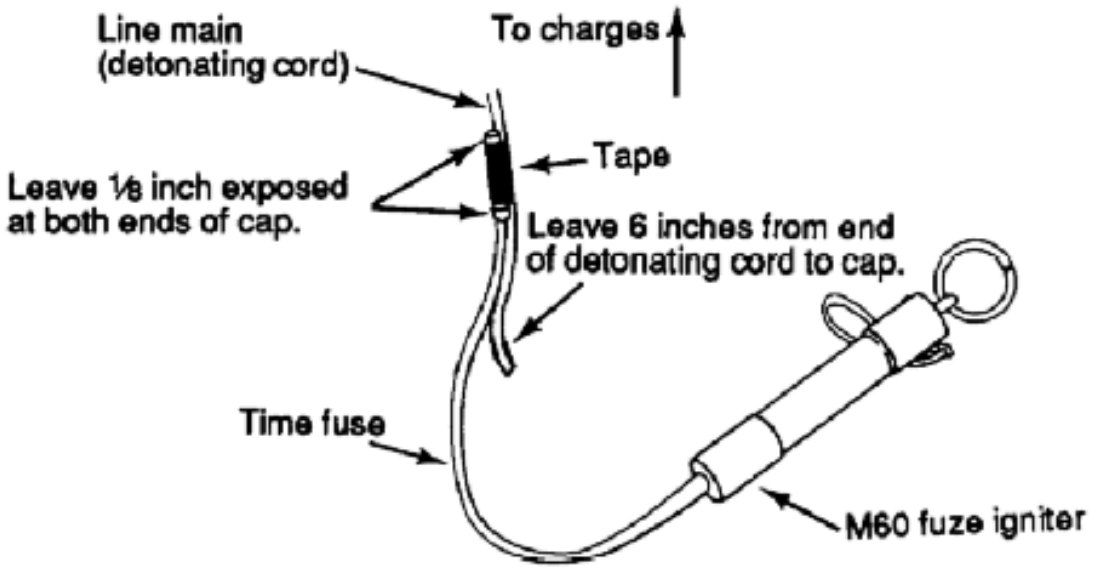


Figure 2-30. Attaching blasting cap to detonating cord

2-14. Detonating-Cord Connections. Use square knots or detonating-cord clips to splice the ends of detonating cord (Figure 2-31). Square knots may be placed in water or in the ground, but the cord must be detonated from a dry end or above ground. Allow 6-inch tails on square knots to prevent misfires from moisture contamination. Paragraph 1-21 (page 1-17) describes the process for connecting detonating cord with detonating-cord clips.

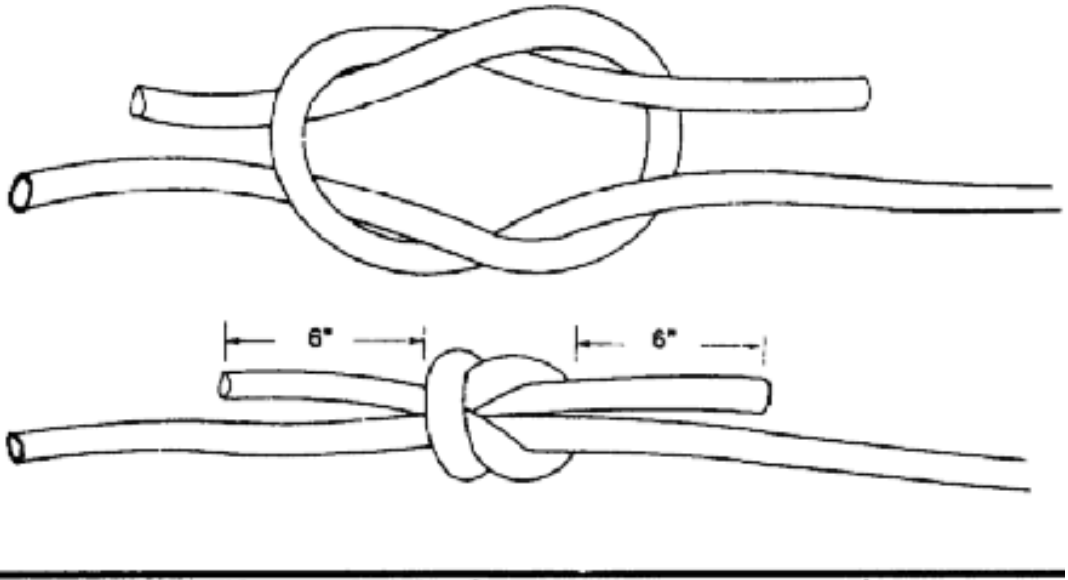


Figure 2-31. Square-knot connections

a. Branch Line. A branch line is nothing more than a length of detonating cord. Attach branch lines to a detonating-cord ring or line main to fire multiple charges. Combining the branch line with an initiation set allows you to fire a single branch line. If possible, branch lines should not be longer than 12 feet from the charge to the ring or line main. A longer branch line is too susceptible to damage that may isolate the charge. Fasten a branch line to a main line with a detonating-cord clip

(Figure 1-18, page 1-17) or a girth hitch with an extra turn (Figure 2-32). The connections of branch lines and ring or line mains should intersect at right (90-degree) angles. If these connections are not at right angles, the branch line may be blown off the line main without complete detonation. To prevent moisture contamination and ensure positive detonation, leave at least 6 inches of the running end of the branch line beyond the tie. It does not matter which side of the knot your 6-inch overhang is on at the connection of the ring or line main.

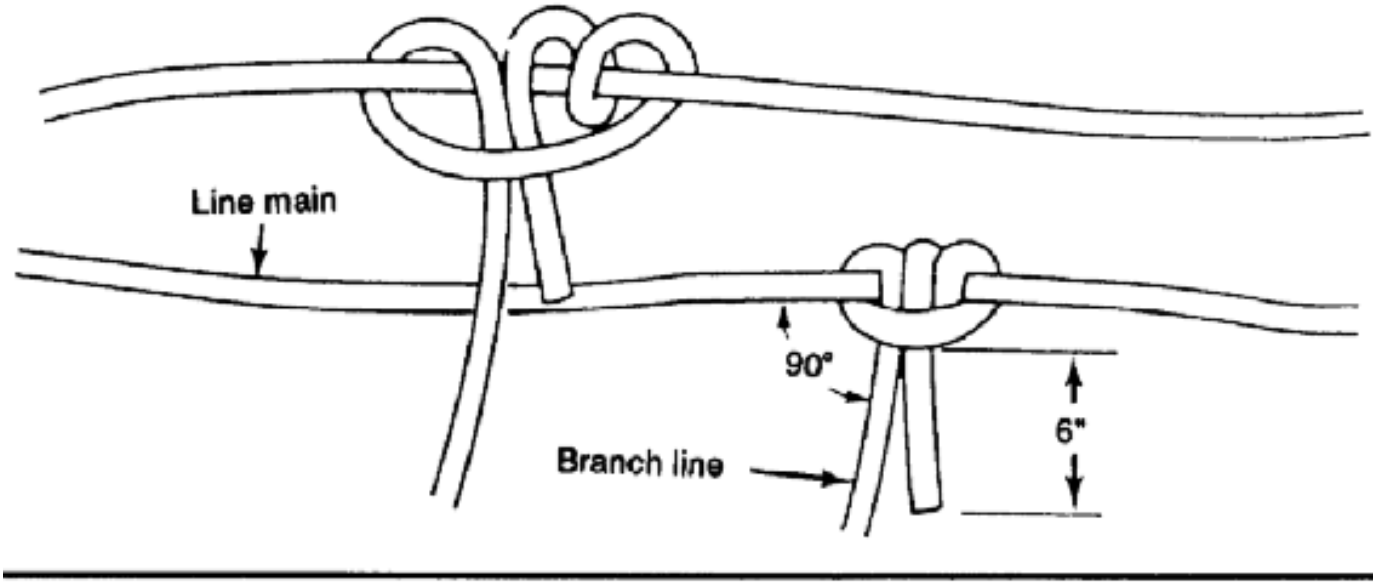


Figure 2-32. Girth hitch with an extra turn

b. Ring Main. Ring mains are preferred over line mains because the detonating wave approaches the branch lines from two directions. The charges will detonate even when them is a break in the ring main. A ring main will detonate an almost unlimited number of charges.

Branch-line connections at the ring main should be at right angles. Kinks in the lines should not be sharp. You can connect any number of branch lines to the ring main; however, never connect a branch line (at the point) where the ring main is spliced. When making branch-line connections, avoid crossing lines. If a line crossing is necessary, provide at least 1 foot of clearance between the detonating cords. Otherwise, the cords will cut each other and destroy the firing system.

(1) Method 1. Make a ring main by bringing the line main back in the form of a loop and attaching it to itself with a girth hitch with an extra turn (Figure 2-33, diagram 1).

(2) Method 2. Make a ring main by making a U-shape with

the detonating cord, and then attaching a detonating-cord crossover at the open end of the U. Use girth hitches with extra turns when attaching the crossover (Figure 2-33, diagram 2). An advantage of the U-shaped ring main is that it provides two points of attachment for initiation sets.

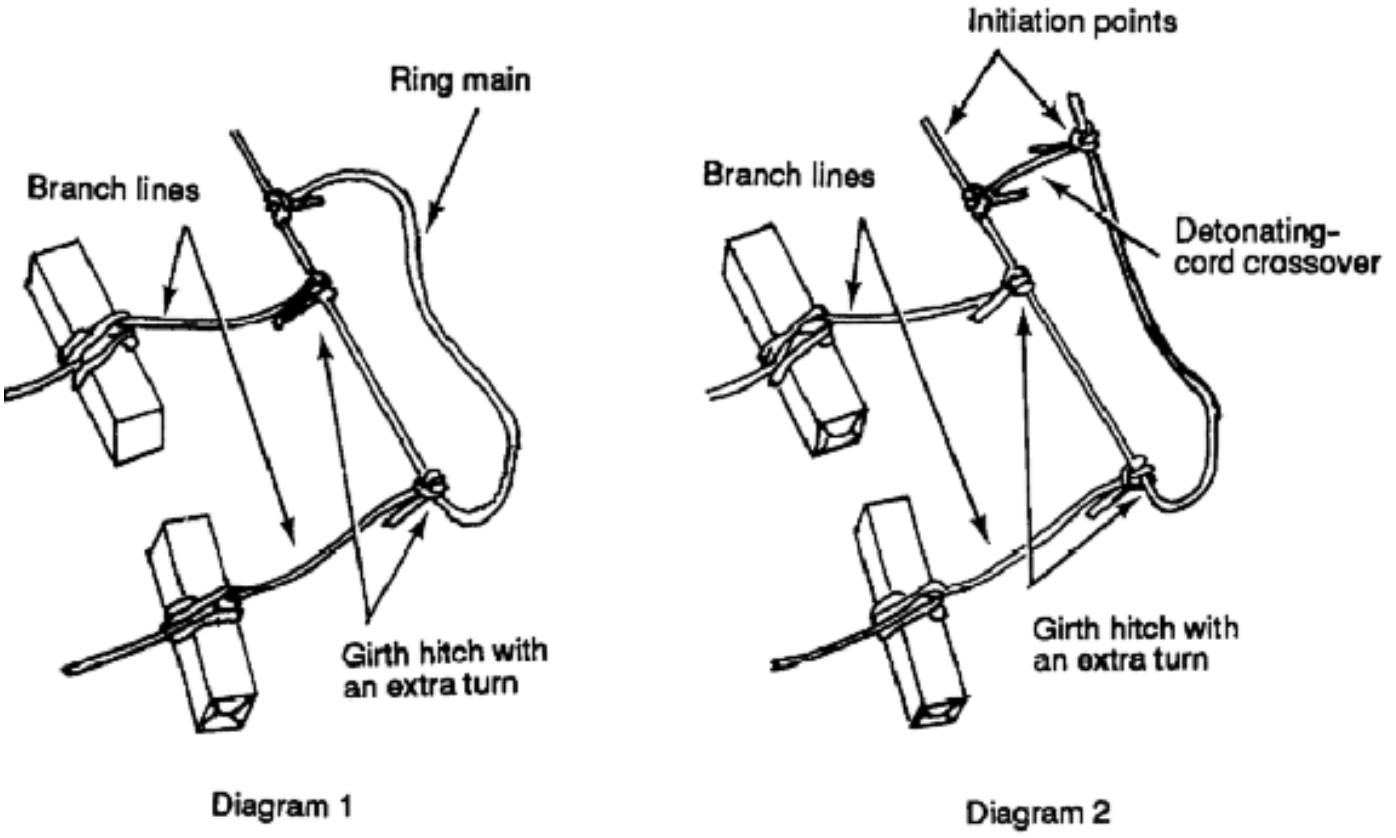


Figure 2-33. Ring mains

c. Line Main. A line main will fire multiple charges (Figure 2-34), but if a break in the line occurs, the detonating wave will stop at the break. When the risk of having a line main cut is unacceptable, use a ring main. Use line mains only when speed is essential and a risk of failure is acceptable. You can connect any number of branch lines to a line main. However, connect only one branch line at any one point unless you use a junction box (Figure 2-35, page 2-28).

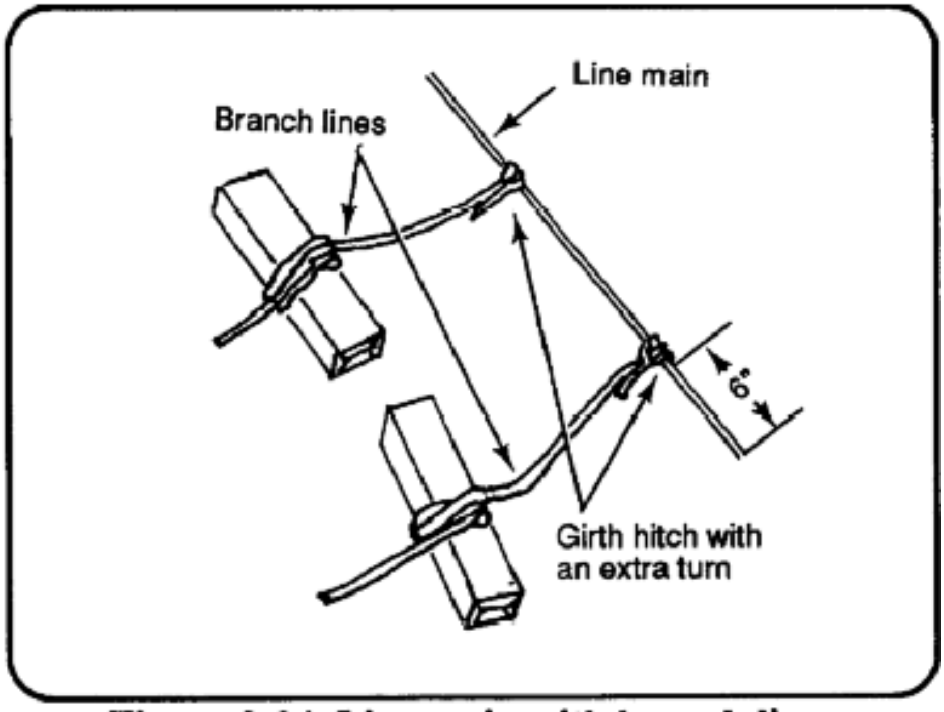


Figure 2-34. Line main with branch lines

2-15. Initiating Lines and Mains.

a. Line Main and Branch Line. Whenever possible, dual initiate a line main or a branch line (Figure 2-36, page 2-28). Place the blasting cap that will detonate first closest to the end of the detonating cord (for example, the electric cap of a combination of initiation sets). Doing this will ensure the integrity of the backup system when the first cap detonates and fails to initiate the line main. Do not try to get both caps to detonate at the same time. This is virtually impossible to do with time fuse. Stagger the detonations a minimum of 10 seconds.

b. Ring Main. Initiate ring mains as shown in Figures 2-33. The blasting caps are still connected as shown in Figure 2-36 (page 2-28), but by having one on each side of the ring main, the chances of both caps becoming isolated from the ring are greatly reduced.

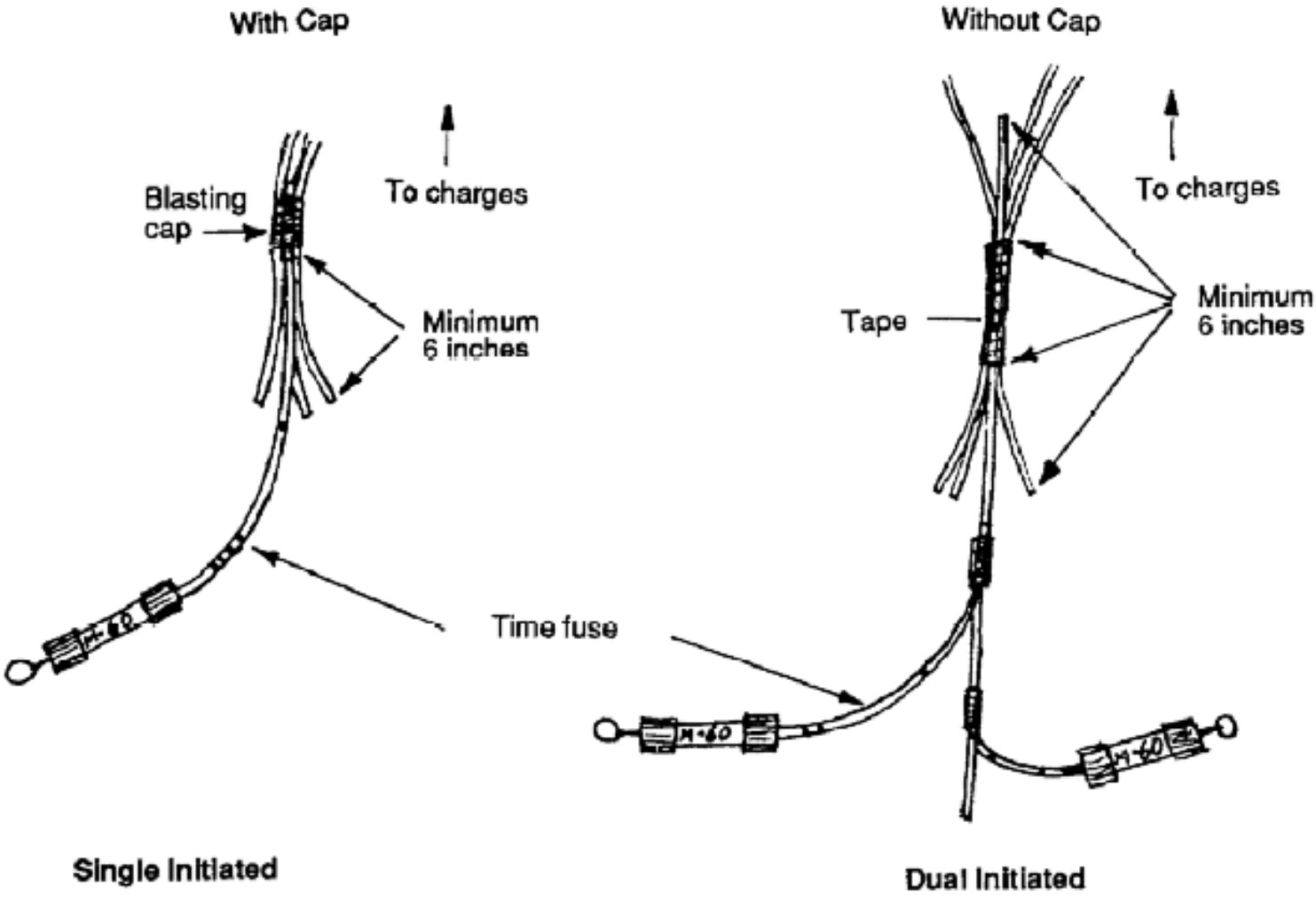


Figure 2-35. Junction box

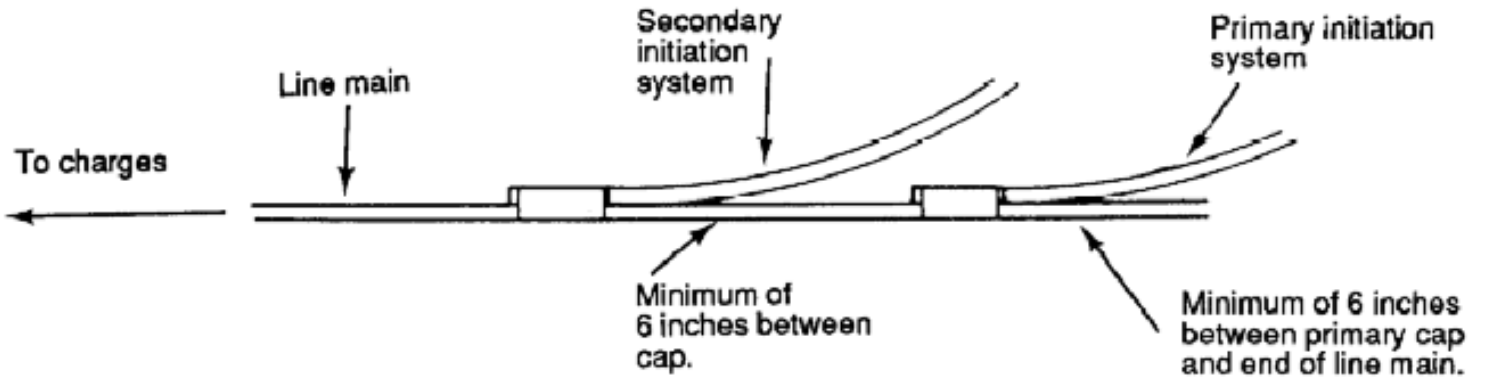

Secondary initiation system
Primary initiation system
Line main
To charges
Minimum of 6 inches between cap.
Minimum of 6 inches between primary cap and end of line main.

Figure 2-36. Attaching blasting caps to a line main

WARNING

When using time or safety fuse, uncoil it and lay it out in a straight line.

Place the time fuse so that the fuse will not curl up and prematurely detonate the blasting cap crimped to it.

NEXT

BACK TO COMMERCIAL EXPLOSIVES

Chapter 3

Calculation and Placement of Charges

Section I. Demolition

3-1. Principles. The amount and placement of explosives are key factors in military demolition projects. Formulas are available to help the engineer calculate the required amount of explosives.

Demolition principles and critical-factor analysis also guide the soldier in working with explosive charges. The available formulas for demolition calculations are based on the following factors:

a. Effects of Detonation. When an explosive detonates, it violently changes into highly compressed gas. The explosive type, density, confinement, and dimensions determine the rate at which the charge changes to a gaseous state. The resulting pressure then forms a compressive shock wave that shatters and displaces objects in its path. A high-explosive charge detonated in direct contact with a solid object produces three detectable destructive affects:

(1) Deformation. The charge’s shock wave deforms the surface of the object directly under the charge. When the charge is placed on a concrete surface, it causes a compressive shock wave that crumbles the concrete in the immediate vicinity of the charge, forming a crater. When

placed on a steel surface, the charge causes an indentation or depression about the size of the contact area of the charge.

(2) Spall. The charge's shock wave chips away at the surface of the object directly under the charge. This action is known as spalling. If the charge is large enough, it will span the opposite side of the object. Because of the difference in density between the target and the air, the charge's compressive shock wave reflects as a tensile shock wave from the free surface, if the target has a free surface on the side opposite the charge. This action causes spalling of the target-free surface.

The crater and spans may meet to forma hole through the wall in concrete demolitions. On a steel plate, the charge may create one span in the shape of the explosive charge, throwing the spall from the plate.

(3) Radial Cracks. If the charge is large enough, the expanding gases can create a pressure load on the object that will cause cracking and therefore displace the material. This effect is known as radial cracking. When placed on concrete walls, the charge may crack the surface into a large number of chunks and project them away from the center of the explosion. When placed on steel plates, the charge may bend the steel away from the center of the explosion.

b. Significance of Charge Dimensions. The force of an

explosion depends on the quantity and power of the explosive. The destructive effect depends on the direction in which the explosive force is directed. To transmit the greatest shock, the charge must have the optimal relationship of contact area and thickness to target volume and density. If you spread a calculated charge too thinly, you will not have provided enough space for the shock wave to reach full velocity before striking the target. In improperly configured explosives (too thin or wrong strength), the shock wave tends to travel in a parallel rather than a perpendicular direction to the surface. As a result, the volume of the target will be too much for the resulting shockwave. Additionally, a thick charge with too small a contact area will transmit a shock wave over too small a target area, with much lateral loss of energy.

c. Significance of Charge Placement. The destructive effect of an explosive charge also depends on the location of the charge in relation to the target size, shape, and configuration. For the most destructive effect, detonate an explosive of the proper size and shape for the size, shape, and configuration of the target. Any significant air or water gap between the target and explosive will lessen the force of the shock wave. Cut explosives (such as sheet or plastic explosives) to fit odd-shaped targets. Whenever possible, place explosive charges to act through the smallest part of the target. Use internal charges to achieve maximum destruction with minimum explosives expense.

Tamping external charges increases their destructive

effect.

3-2. Types of Charges.

a. Internal Charges. Place internal charges in boreholes in the target. Confine the charges with tightly packed sand, wet clay, or other material (stemming). Stemming is the process of packing material on top of an internal borehole or crater charge. Fill and tamp stemming material against the explosive to fill the borehole to the surface. In drill holes, tamp the explosive as it is loaded into the hole. Tamp stemming material only with nonsparking equipment.

b. External Charges. Place external charges on the surface of the target. Cover and tamp the charges with tightly packed sand, clay, or other dense material. Stemming material may be loose or in sandbags. To be most effective, make the thickness of the tamping material at least equal to the breaching radius. Tamp small breaching charges on horizontal surfaces with several inches of wet clay or mud.

3-3. Charge Calculations. Determine the amount of explosives required for any demolition project by calculation, based on the following critical factors:

a. Type and Strength of Materials in Targets. A target may be timber, steel, or other material.

Concrete may be reinforced with steel, thereby increasing

the concrete's strength.

b. Size, Shape, and Configuration of Target. These characteristics all influence the required type and amount of explosives. For example, large or odd-shaped targets, such as concrete piers and steel beams, are more economically demolished with multiple charges than with a single charge.

c. Desired Demolition Effect. Consider the extent of the demolition project and the other desired effects, such as the direction trees will fall when constructing an abatis.

d. Type of Explosive. The characteristics of each type of explosive determine its application for demolition purposes. Tables 1-1 and 1-2 (pages 1-2 and 1-5) list these characteristics.

e. Size and Placement of Charge. When using external charges without considering placement techniques, use a flat, square charge with a thickness-to-width ratio of 1:3. In general, charges of less than 5 pounds should be at least 1 inch thick. Charges from 5 to 40 pounds should be 2 inches thick. Charges of 40 pounds or more should be 4 inches thick. Fasten charges to the target using wire, adhesive compound, tape, or string. Prop charges against targets with wooden or metal frames made of scrap or other available materials or place the charges in boreholes.

f. Method of Tamping. If you do not completely seal or

confine the charge or if you do not ensure the material surrounding the explosive is balanced on all sides, the explosive's force will escape through the weakest spot. To keep as much explosive force as possible on the target, pack material around the charge to fill any empty space. This material is called tamping material and the process is called tamping. Sandbags and earth are examples of common tamping materials.

Always tamp charges with a nonsparking instrument.

g. Direction of Initiation. The direction in which the shockwave travels through the explosive charge will affect the rate of energy transmitted to the target. If the shock wave travels parallel to the surface of the target (Figure 3-1, diagram 1), the shock wave will transmit less energy over a period of time than if the direction of detonation is perpendicular to the target. For best results, initiate the charge in the center of the face opposite the face in contact with the target.

3-4. Charge Selection and Calculation.

a. Selection. Explosive selection for successful demolition operations is a balance between the critical factors listed above and the practical aspects: target type; the amount and types of explosives, materials (such as sandbags), equipment, and personnel available; and the amount of time available to accomplish the mission.

b. Calculation. Use the following procedure to determine

the weight (P) of the explosive required for a demolition task, in pounds of TNT. If you use an explosive other than TNT, adjust P accordingly by dividing P for TNT by the relative effectiveness (RE) factor of the explosive you plan to use (Table 1-1, page 1-2). Use the following six-step, problem-solving format for all charge

calculations:

(1) Determine the critical dimensions of the target.

(2) Calculate the weight of a single charge of TNT to two decimal places by using the appropriate demolition formula (do not round). If your calculations are for TNT, skip to Step 4.

(3) Divide the quantity of explosive by the RE factor (carry the calculations to two decimal places, and do not round). If you are using TNT, skip this step.

(4) Determine the number of packages of explosive for a single charge by dividing the individual charge weight by the standard package weight of the chosen explosive. Round this result to the next-higher, whole package. Use volumes instead of weights for special purpose charges (ribbon, diamond, saddle, and similar charges).

(5) Determine the number of charges for the target.

(6) Determine the total quantity of explosives required to destroy the target by multiplying the number of charges

(Step 5) by the number of packages required per charge (Step 4).

Section II. Normal Cutting Charges

3-6. Steel-Cutting Charges.

WARNING

Steel-cutting charges produce metal fragments.

Proper precautions should be taken to protect personnel. Refer to Table 6-3, page 6-7.

a. Target Factors. The following target factors are critical in steel-structure demolitions, more so than with other materials:

(1) Target Configuration. The configuration of the steel in the structure determines the type and amount of charge necessary for successful demolition. Examples of structured steel are I-beams, wide-flange beams, channels, angle sections, structural tees, and steel plates used in building or bridge construction. Example A-3 (page A-3) shows how to calculate steel-cutting charges for wide-flange beams and girders.

(2) Target Materials. In addition to its configuration, steel also has varied composition:

High-carbon steel. Metal-working dies and rolls are normally composed of high-carbon steel and are very

dense.

Alloy steel. Gears, shafts, tools, and plowshares are usually composed of alloy steel. Chains and cables are often made from alloy steel; however, some chains and cables are composed of high-carbon steel. Alloy steel is not as dense as high-carbon steel.

Cast iron. Some steel components (such as railroad rails and pipes) are composed of cast iron. Cast iron is very brittle and easily broken.

Nickel-molybdenum steel. This type of steel cannot be cut easily by conventional steel-cutting charges. The jet from a shaped charge will penetrate it, but cutting requires multiple charges or linear-shaped charges. Nickel-molybdenum steel shafts can be cut with a diamond charge. However, the saddle charge will not cut nickel-molybdenum shafts. Therefore, use some method other than explosives to cut nickel-molybdenum steel, such as thermite or acetylene or electrical cutting tools.

b. Explosives Factors. In steel-cutting charges, the type, placement, and size of the explosive are important. Confining or tamping the charge is rarely practical or possible. The following factors are important when selecting steel-cutting charges:

(1) Type. Select steel-cutting charges that operate with a cutting effect. Percussive charges are not very effective for steel cutting. Plastic explosive (C4) and sheet explosive

(Ml 18) are best. These explosives have very effective cutting power and are easily cut and shaped to fit tightly into the grooves and angles of the target. These explosives are particularly effective when demolishing structural steel, chains, and steel cables.

(2) Placement (Figure 3-7). To achieve the most effective initiation and results, ensure that—

The charge is continuous over the complete line of the proposed cut.

There is close contact between the charge and the target.

The width of the charge’s cross section is between one and three times its thickness. Do not use charges more than 6 inches thick because you can achieve better results by increasing the width rather than the thickness.

Long charges are primed every 4 to 5 feet. If butting C4 packages end to end along the line of the cut, prime every fourth package.

The direction of initiation is perpendicular to the target (Figure 3-1).

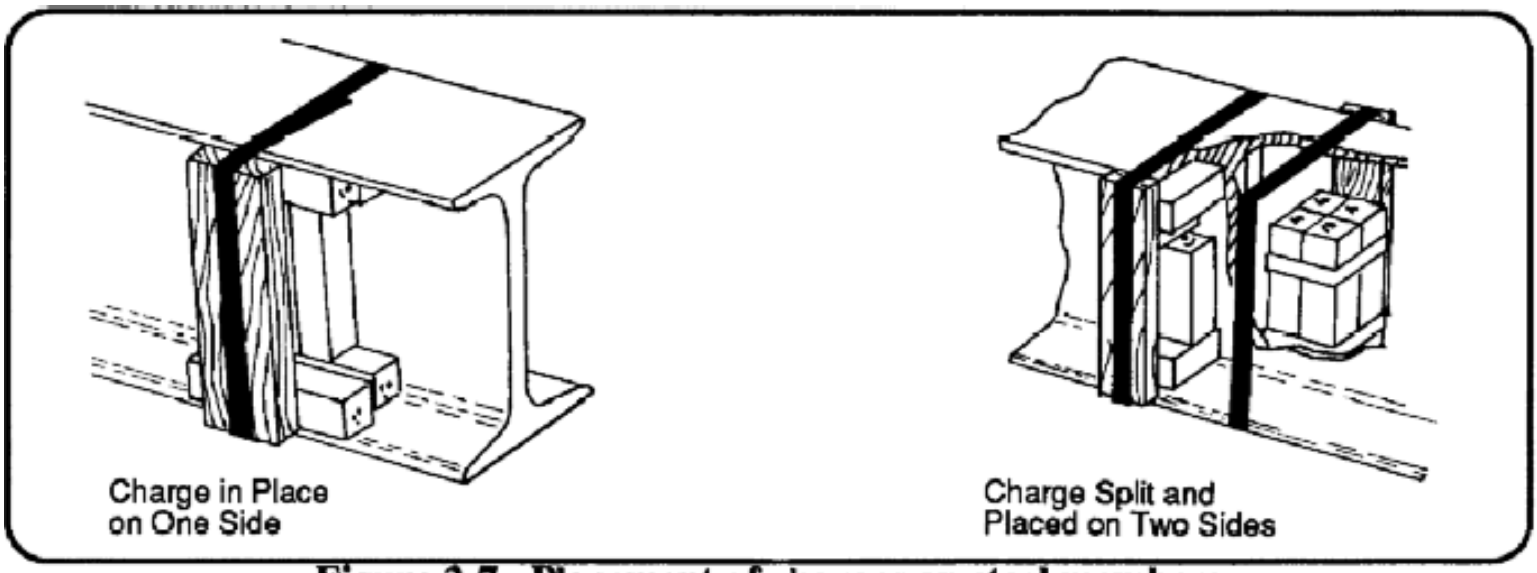


Figure 3-7. Placement of charges on steel members

(3) Size. The size of the charge is dictated by the target steel's type and size and the type of charge selected. Use either C4 or TNT block explosives for cutting steel. C4 works best. Each steel configuration requires a unique charge size.

(a) Block charge. Generally, the following formula will give you the size of charge necessary for cutting I-beams, built-up girders, steel plates, columns, and other structural steel sections. (When calculating cutting charges for steel beams, the area for the top flange, web, and bottom flange must be calculated separately.) Built-up beams also have rivet heads and angles or welds joining the flanges to the web. You must add the thickness of one rivet head and the angle iron to the flange thickness when determining the thickness of a built-up beam's flange. Use the thinnest point of the web as the web thickness, ignoring rivet-head and angle-iron thickness. Cut the lattice of lattice-girder webs diagonally by placing a charge on each lattice along the line of the cut. Use tables 3-2

and 3-3 (page 3-10) to determine the correct amount of C4 necessary for cutting steel sections. Use the following formula to determine the required charge size (Table 3-3, page 3-10, is based on this formula):

$$P = (\frac{3}{8})A \text{ or } P = 0.375A$$

where–

P = TM required, in pounds.

A = cross-sectional area of the steel member, in square inches.

Table 3-2. Hasty steel-cutting chart for TNT

Average Thickness of Section (in)	Pounds of explosive* for rectangular steel sections of given dimensions																
	Height of section (in)																
	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24
¼	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.7	1.9	2.1	2.3
⅜	0.3	0.5	0.6	0.7	0.9	1.1	1.2	1.3	1.4	1.6	1.7	2.0	2.3	2.6	2.8	3.1	3.4
½	0.4	0.6	0.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.7	3.0	3.4	3.8	4.2	4.5
⅝	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.2	2.4	2.7	2.9	3.3	3.8	4.3	4.7	5.2	5.7
¾	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.1	3.4	4.0	4.5	5.1	5.7	6.3	6.8
⅞	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.0	3.3	3.7	4.0	4.6	5.3	6.0	6.6	7.3	7.9
1	0.8	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	5.3	6.0	6.8	7.5	8.3	9.0

*TNT

Table 3-3. Hasty steel-cutting chart for C4

Section Thickness (Inches)	Weight of Composition C4 Required for Rectangular Steel Sections (Height or Width, in Inches)													
	2	3	4	5	6	8	10	12	14	16	18	20	22	24
1/4	0.2	0.3	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.5	1.6	1.8
3/8	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.1	2.4	2.6
1/2	0.3	0.5	0.6	0.8	0.9	1.2	1.5	1.8	2.1	2.3	2.6	2.9	3.2	3.4
5/8	0.4	0.6	0.8	0.9	1.1	1.5	1.8	2.2	2.5	2.9	3.2	3.5	3.9	4.3
3/4	0.5	0.7	0.9	1.1	1.3	1.8	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1
7/8	0.6	0.8	1.1	1.3	1.5	2.1	2.5	3.0	3.5	4	4.5	5.0	5.5	5.9
1	0.6	0.9	1.2	1.5	1.8	2.3	2.9	3.4	4.0	4.5	5.1	5.6	6.2	6.8

NOTE: Round UP to the nearest 1/10 pound when calculating charge sizes.

To use this table:
1. Measure each rectangular section of the total member separately.
2. Find the approparite charge size for the rectangular section from the table. If the section dimension is not listed in the table, use the next-larger dimension.
3. Add the individual charges for each section to obtain the total charge weight.

(b) High-carbon or alloy steel. Use the following formula to determine the required charge for cutting high-carbon or alloy steel:

$$P = D^2$$

where–

P = TNT required, in pounds.

D = diameter or thickness of section to be cut, in inches.

(c) Steel bars, rods, chains, and cables (up to 2 inches). The size of these materials makes proper charge placement difficult. For example, Figure 3-8 shows charge placement on a chain. If the explosive is long enough to bridge both sides of the link or is large enough to fit snugly between the two links, use one charge. If the explosive is not large enough to bridge both sides, use two charges. Use the following amount of explosive:

For materials up to 1 inch in diameter or thickness, use 1 pound of explosive.

For materials between 1 and 2 inches in diameter or thickness, use 2 pounds of explosive.

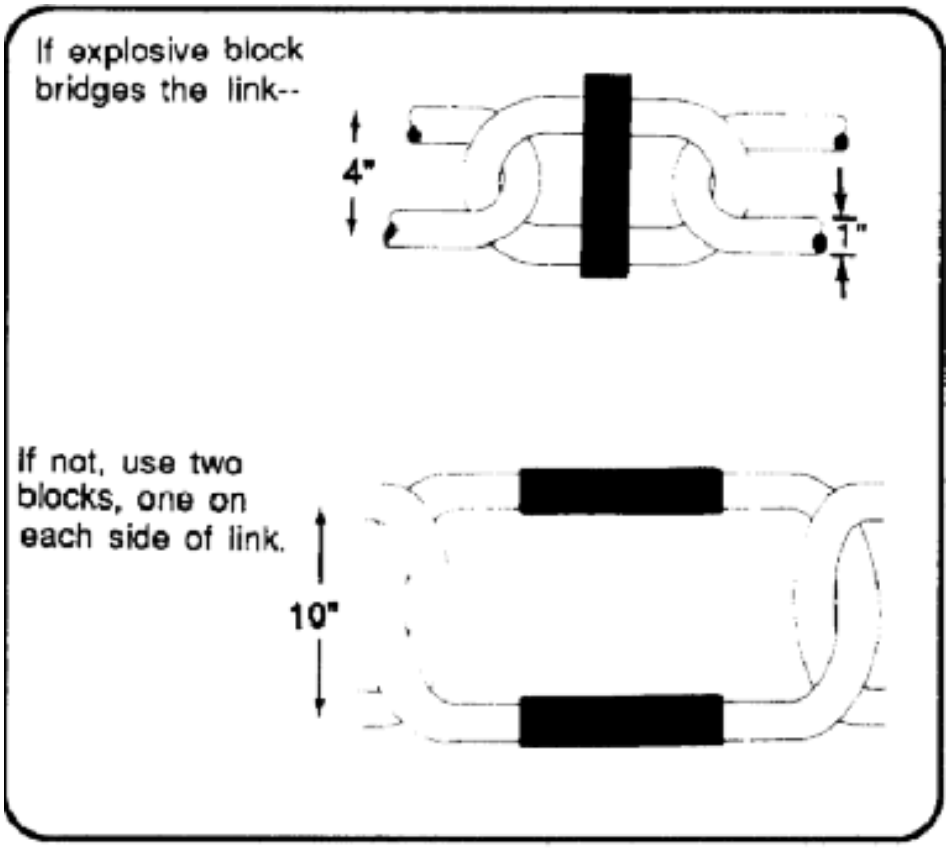


Figure 3-8. Charge placement on chains

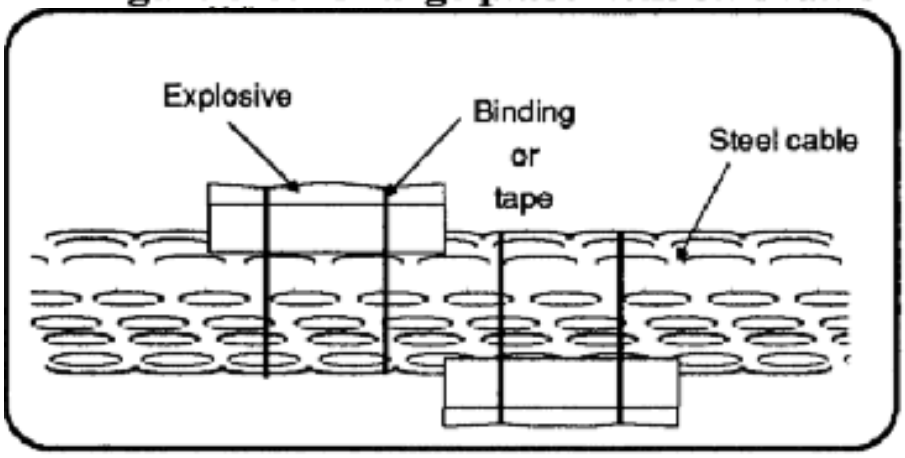


Figure 3-9. Charge placement on steel

(d) Steel bars, rods, chains, and cables (over 2 inches). When the target diameter or thickness is 2 inches or greater, use equation 3-4.

When the thickness or diameter is 3 inches or greater, place half of the charge on each side of, the target and stagger the placement to produce the maximum shearing

effect (Figure 3-9).

(e) Railroad rails. The height of the railroad rail is the critical dimension for determining the amount of explosive required.

For rails 5 inches or more in height, crossovers, and switches, use 1 pound of C4 or TNT. For rails less than 5 inches high, use 1/2 pound of C4 or TNT (Figure 3-10, page 3-12). Railroad frogs require 2 pounds of C4 or TNT. Place the charges at vulnerable points, such as frogs, curves, switches, and crossovers, if possible. Place the charges at alternate rail splices for a distance of 500 feet.

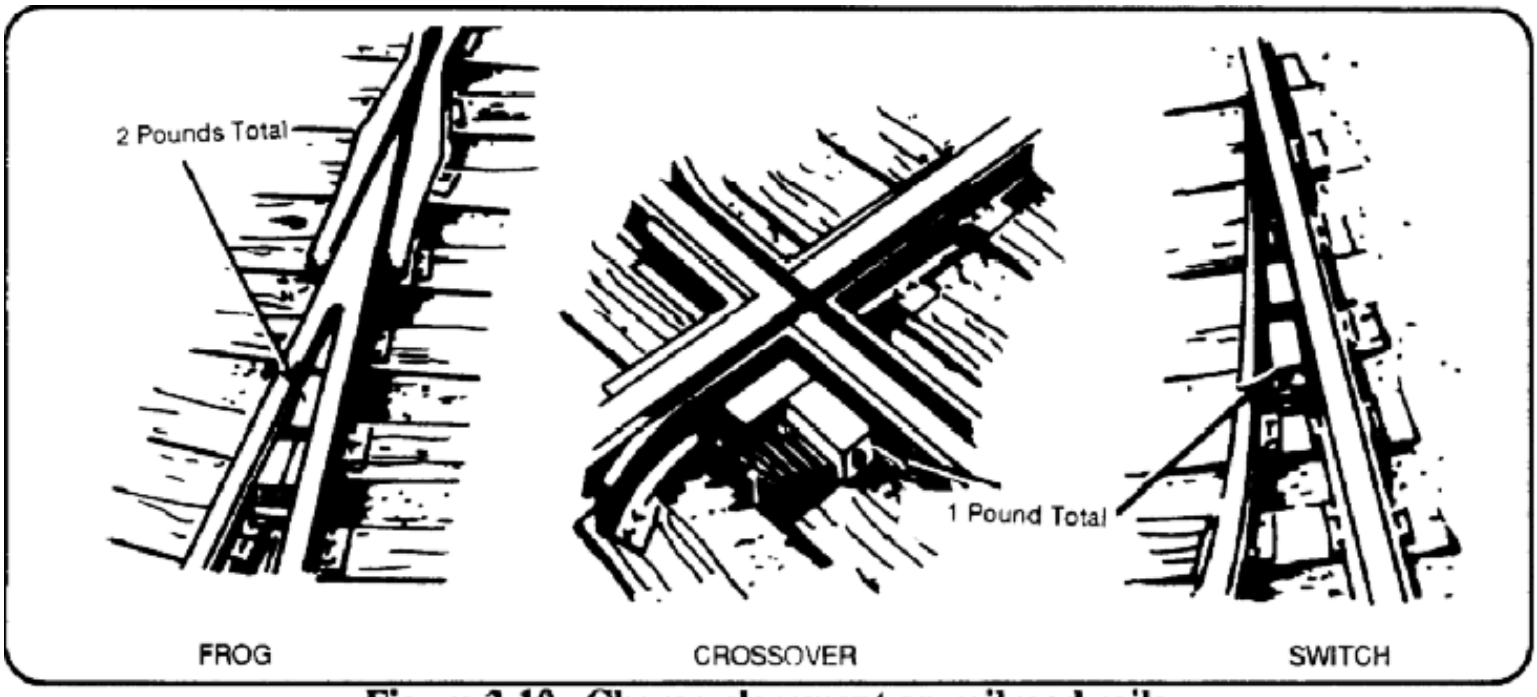


Figure 3-10. Charge placement on railroad rails

Section III. Special Cutting Charges

3-7. Purpose. When time and circumstances permit, you can use the special cutting charges (ribbon, saddle, and diamond charges) instead of conventional cutting charges. These charges may require extra time to prepare, since

they require exact and careful target measurement to achieve optimal effect. With practice, an engineer can become proficient at calculating, preparing, and placing these charges in less time than required for traditional charges. Special cutting charges use considerably less explosive than conventional charges. Use plastic-explosive (M112) or sheet-explosive (Ml18 or Ml86) charges as special charges. C4 requires considerable cutting, shaping, and molding, which may reduce its density and, therefore, its effectiveness. Sheet explosive is more suitable than C4, since sheet explosive is more flexible and requires less cutting.

Use of these charges requires considerable training and practice. The charges are thin and require blasting caps crimped to a detonating-cord branch line for initiation. (A detonating-cord knot will work but is difficult to place and can ruin the advantage of the special charge shape).

3-8. Ribbon Charges. Use these charges to cut flat, steel targets up to 3 inches thick (Figure 3- 11).

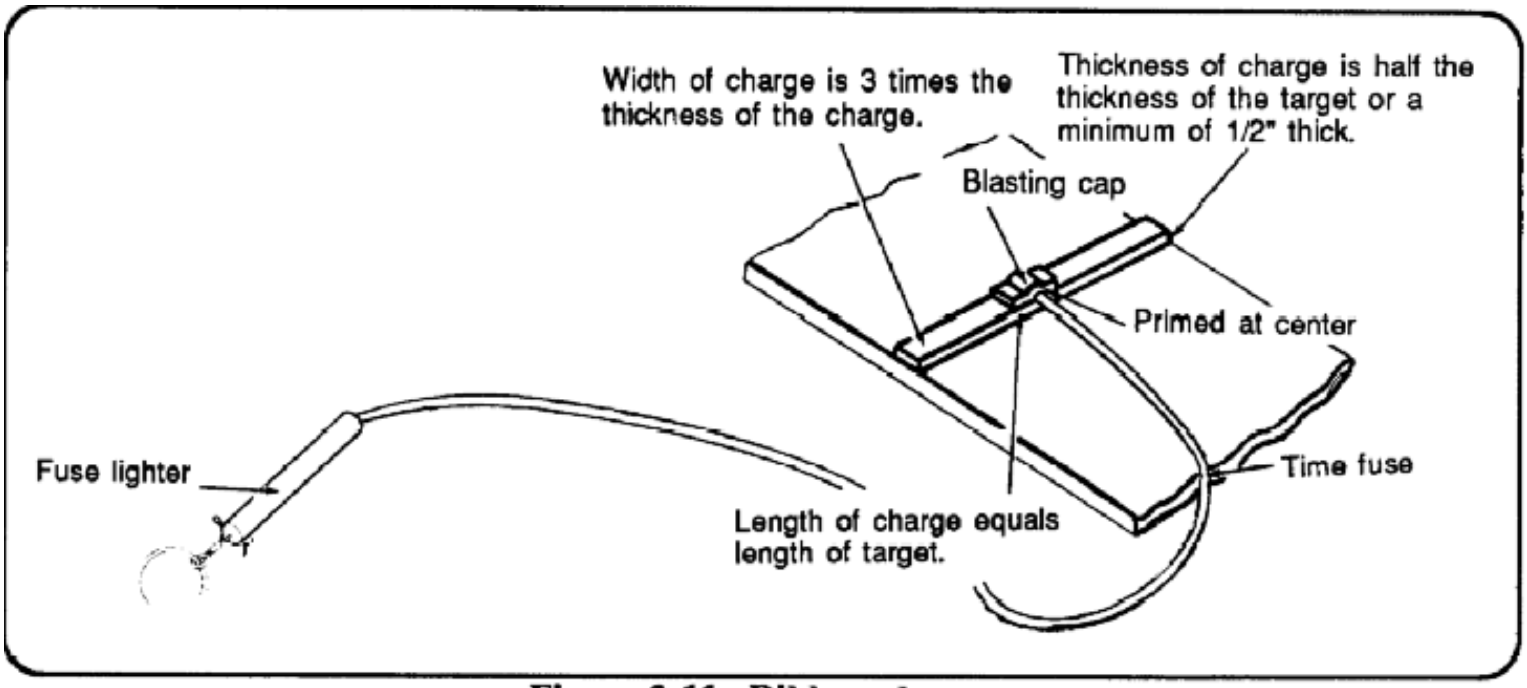

Width of charge is 3 times the thickness of the charge.
Thickness of charge is half the thickness of the target or a minimum of 1/2" thick.
Blasting cap
Primed at center
Fuse lighter
Time fuse
Length of charge equals length of target.

Figure 3-11. Ribbon charge

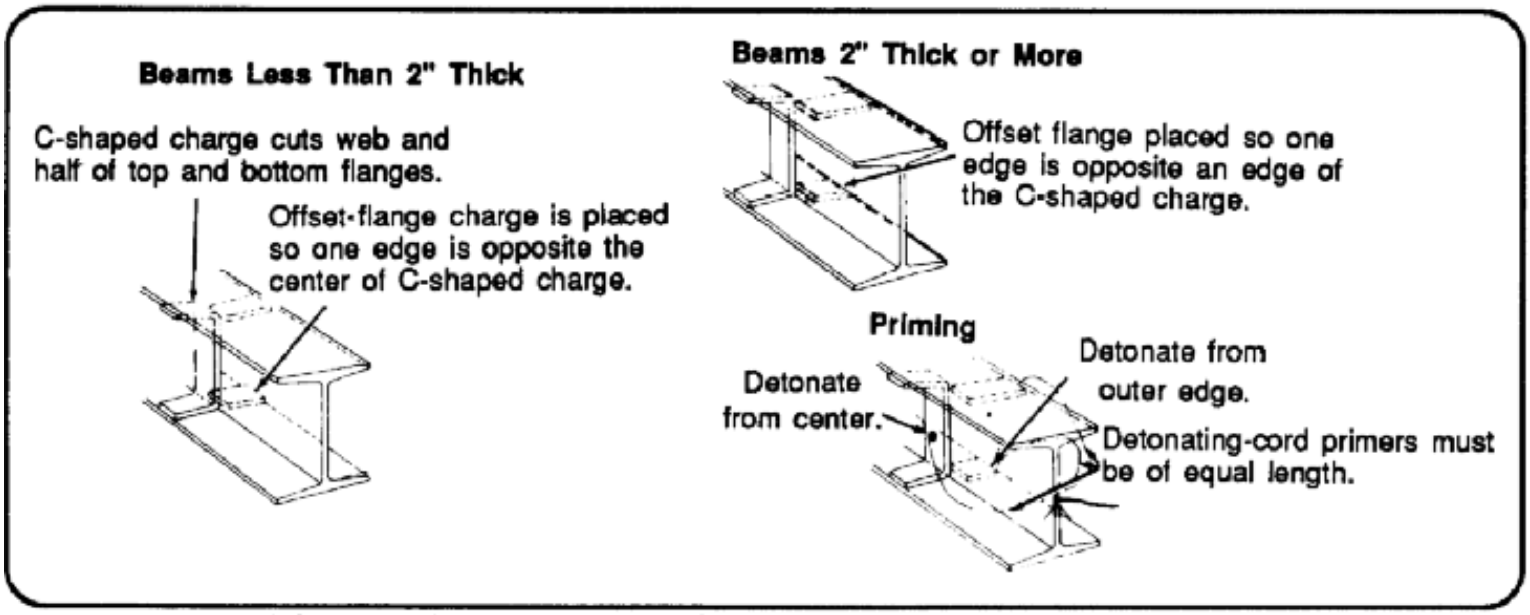

Beams Less Than 2" Thick
C-shaped charge cuts web and half of top and bottom flanges.
Offset-flange charge is placed so one edge is opposite the center of C-shaped charge.
Beams 2" Thick or More
Offset flange placed so one edge is opposite an edge of the C-shaped charge.
Priming
Detonate from center.
Detonate from outer edge.
Detonating-cord primers must be of equal length.

Figure 3-12. Placement of ribbon charge on structural steel

Make the charge thickness one-half the target thickness but never less than 1/2 inch. Make the charge width three times the charge thickness and the length of the charge equal to the length of the desired cut. Detonate the ribbon charge from the center or from either end. When using the ribbon charge to cut structural steel sections, place the charge as shown in Figure 3-12. The detonating-cord branch lines must be the same length and must connect in a junction box (Figure 2-35, page 2-27). Example A-5

(page A-5) shows how to calculate steel-cutting charges for steel plates. The formula for the ribbon charge is as follows:

a. Charge Thickness. The charge thickness equals one half the target's thickness; however, it will never be less than 1/2 inch.

b. Charge Width. The charge width is three times charge thickness.

c. Charge Length. The charge length equals the length of the desired cut.

3-9. Saddle Charge. This steel-cutting method uses the destructive effect of the cross fracture formed in the steel by the base of the saddle charge (end opposite the point of initiation). Use this charge on mild steel bars, whether round, square, or rectangularly shaped, up to 8 square inches or 8 inches in diameter (Figure 3-13, page 3-14). Make the charge a uniform I-inch thick. Example A-7 (page A-7) shows how to calculate steel-cutting charges for steel bars, Determine the dimensions of the saddle charge as follows:

a. Dimensions.

(1) Thickness. Make the charge 1 inch thick (standard thickness of Ml 12 block explosive).

(2) Base Width. Make the base width equal to one-half the

target circumference or perimeter.

(3) Long-Axis Length. Make the long-axis length equal to the target circumference or perimeter.

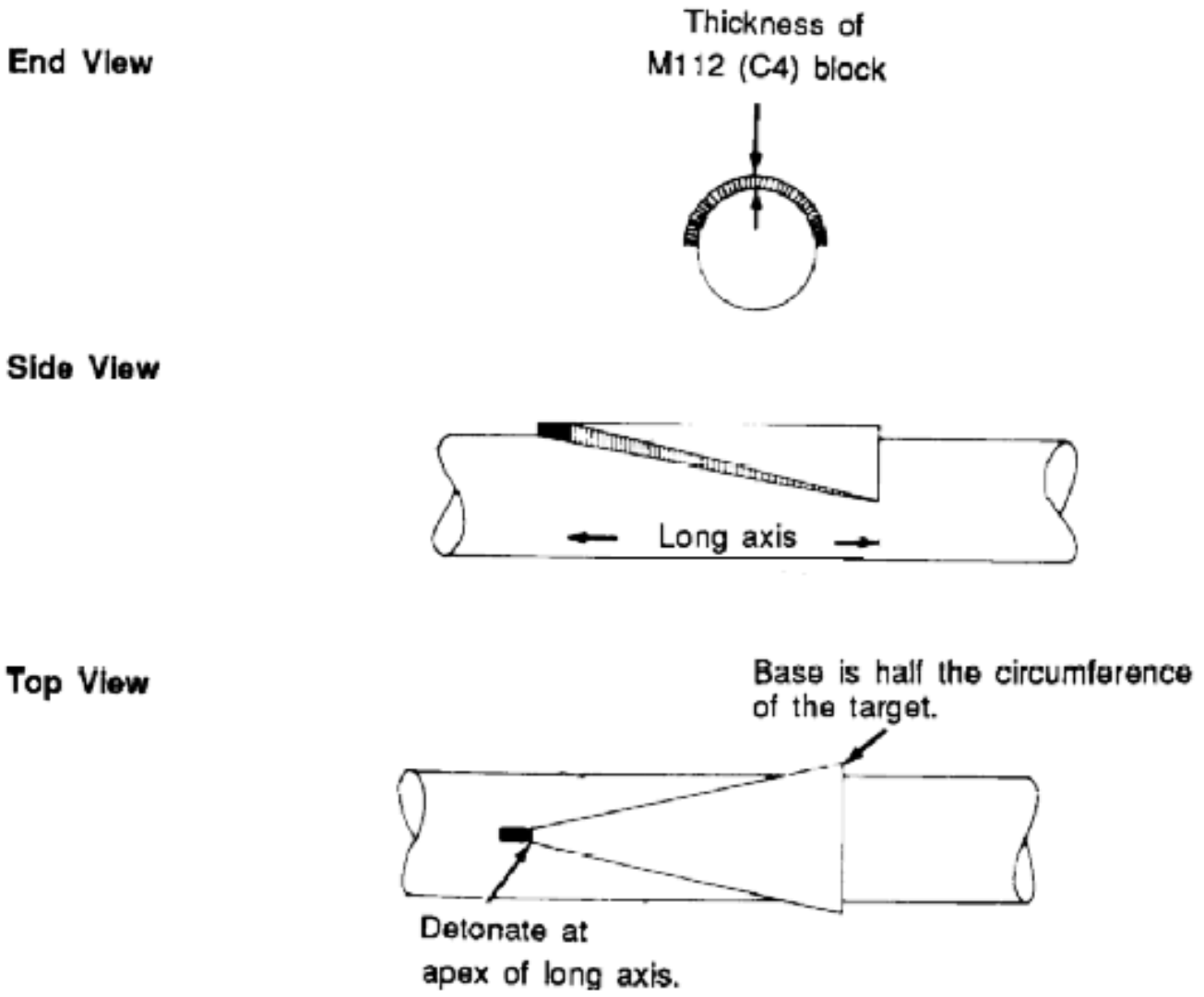


Figure 3-13. Saddle charge

b. Detonation. Detonate the saddle charge by placing a blasting cap at the apex of the long axis.

c. Placement. The long axis of the saddle charge should be parallel with the long axis of the target. Cut the charge to the correct shape and dimensions and then place it around the target. Ensure the charge maintains close

contact with the target by taping the charge to the target.

3-10. Diamond Charge. This technique, the stress-wave method, employs the destructive effect of two colliding shock waves. The simultaneous detonation of the charge from opposite ends (Figure 3-14) produces the shock waves. Use the diamond charge on high-carbon or alloy steel bars up to 8 inches in diameter or having cross-sectional areas of 8 square inches or less. Example A-8 (page A-7) shows how to calculate steel-cutting charges for high-carbon steel.

a. Dimensions.

(1) Thickness. Make the charge 1 inch thick (standard thickness of Ml12 block explosive).

(2) Long-Axis Length. Make the long-axis length equal to the target circumference or perimeter.

(3) Short-Axis Length. Make the short-axis length equal to one-half the target circumference or perimeter.

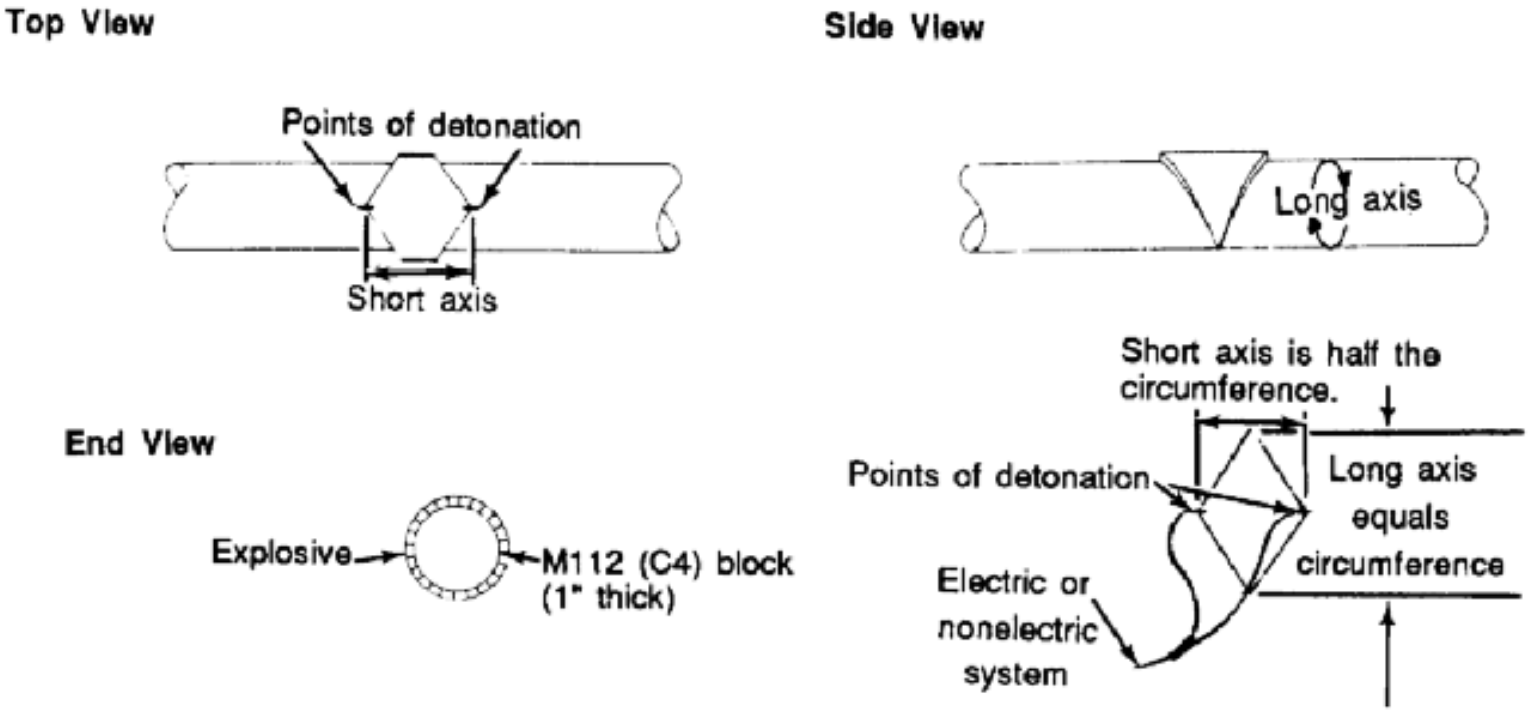


Figure 3-14. Diamond charge

b. Placement. Place the explosive completely around the target so that the ends of the long axes touch. You may have to slightly increase the charge dimensions to do this. To ensure adequate contact with the target, tape the charge to the target.

c. Priming. Prime the diamond charge (Figure 3-14) with two detonating cord branch lines using one of the following methods:

Detonating cord knots (Figure 2-15, page 2- 14).

Two electric blasting caps in a series circuit (Figure 2-7, page 2-8).

Two nonelectric blasting caps (Figure 2-35, page 2-27).

NOTE: When using detonating cord knots or nonelectric blasting caps, the branch lines must be the same length.

Section IV. Breaching Charges

3-11. Critical Factors. Use breaching charges to destroy bridge piers, bridge abutments, and permanent field fortifications. The size, shape, placement, and tamping or confinement of breaching charges are critical to success. The size and confinement of the explosive are the most critical factors because the targets are usually very strong and bulky. The intent of breaching charges is to produce and transmit sufficient energy to the target to make a crater and create spalling. Breaching charges placed against reinforced concrete will not cut metal reinforcing bars. Remove or cut the reinforcement with a steel-cutting charge after the concrete is breached.

3-12. Computation.

a. Formula. Determine the size of the charge required to breach concrete, masonry, rock, or similar material by using the following formula:

$$P = R^3KC$$

where—

P = TNT required, in pounds.

R = breaching radius, in feet.

K = material factor, which reflects the strength, hardness, and mass of the material to be demolished, (Table 3-4).

Table 3-4. Material factor (*K*) for breaching charges

Material	Breaching Radius (*R*)	*K*
Earth	All values	0.07
Poor masonry, Shale, Hardpan, Good timber, Earth construction	Less than 1.5 m (5 ft) 1.5 m (5 ft) or more	0.32 0.29
Good masonry, Concrete block, Rock	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 ft) 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	0.88 0.48 0.40 0.32 0.27
Dense concrete, First-class masonry	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 ft) 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	1.14 0.62 0.52 0.41 0.35
Reinforced concrete (Factor does not consider cutting concrete)	0.3 m (1 ft) or less Over 0.3 m (1 ft) to less than 0.9 m (3 ft) 0.9 m (3 ft) to less than 1.5 m (5 f)t 1.5 m (5 ft) to less than 2.1 m (7 ft) 2.1 m (7 ft) or more	1.76 0.96 0.80 0.63 0.54

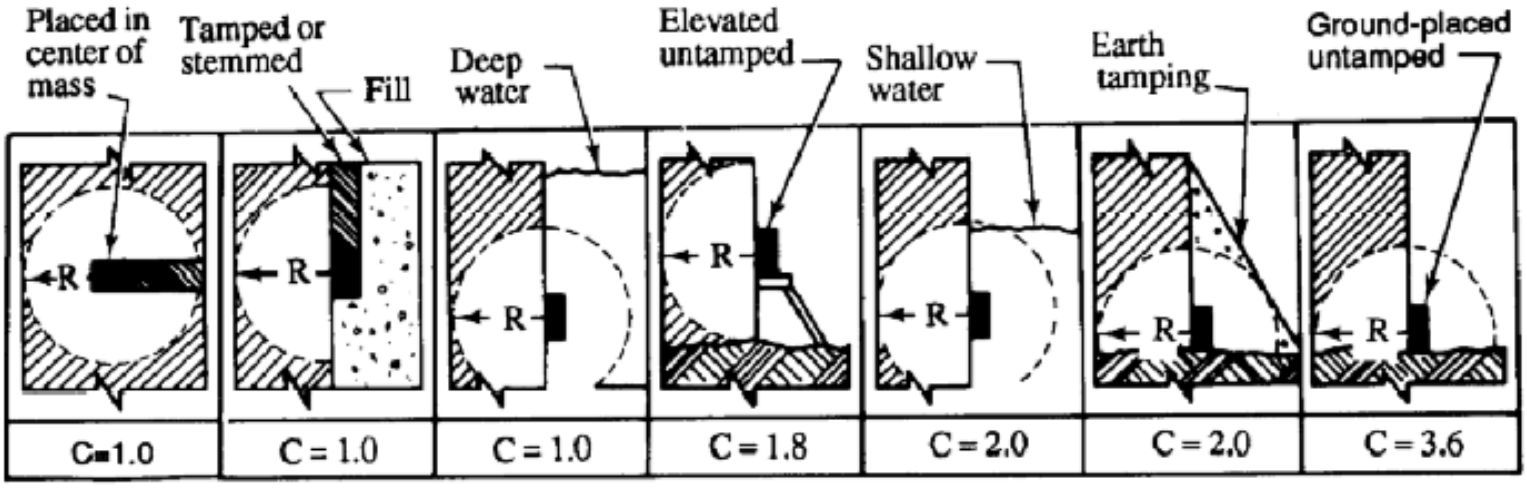


Figure 3-15. Tamping factor (*C*) for breaching charges

C = tamping factor, which depends on the location and tamping of the charge (Figure 3-15).

b. Breaching Radius (R). The breaching radius for external charges is equal to the thickness of the target being breached. For internal charges placed in the center of the target's mass, the breaching radius is one half the thickness of the target. If the charge is placed at less than half the mass thickness, the breaching radius is the longer of the distances from the center of the charge to the outside surfaces of the target. For example, when breaching a 4-foot wall with an internal charge placed 1 foot into the wall, the breaching radius is 3 feet (the longest distance from the center of the explosive to an outside target surface). If placed at the center of the wall's mass, the explosive's breaching radius is 2 feet (one-half the thickness of the target). The breaching radius is 4 feet for an external charge on this wall. Round values of R to the next-higher ¼-foot distance for internal charges and to the next-higher ½-foot distance for external charges.

c. Material Factor (K). K represents the strength and hardness of the target material. Table 3-4 gives values for K for various types and thicknesses of material. When you are unable to positively identify the target material, assume the target consists of the strongest type of material in the general group. Always assume concrete is reinforced and masonry is first-class unless you know the exact condition and construction of the target materials.

d. Tamping Factor (C). C depends on the charge location and materials used for tamping.

Figure 3-15 illustrates methods for placing charges and gives the values of C for both tamped and untamped charges. When selecting a value for C from Figure 3-15, do not consider a charge tamped with a solid material (such as sand or earth) as fully tamped unless you cover the charge to a depth equal to or greater than the breaching radius.

3-13. Breaching Reinforced Concrete. Table 3-5 (page 3-18) gives the number of C4 packages required for breaching reinforced-concrete targets. Example A-9 (page A-8) shows how to calculate the breaching charge for a reinforced-concrete pier. The amounts of C4 in the table are based on equation 3-6. To use the table, do the following:

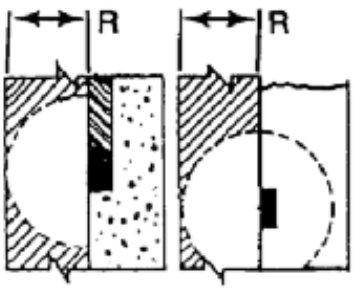
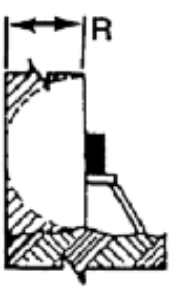
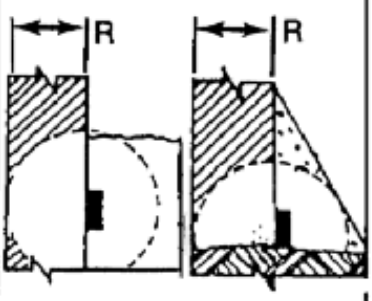
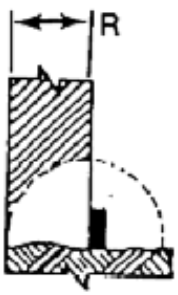
a. Measure the concrete thickness.

b. Decide how the charge will be placed against the target. Compare the method of placement with the diagrams at the top of the Table 3-5 (page 3-18). If in doubt about which column to use, always use the column that lists the greatest amount of explosive.

c. Using the column directly under the chosen placement method, select the amount of explosive required, based on target thickness. For example, 200 packages of C4 are required to breach a 7-foot reinforced-concrete wall with

an untamped charge placed 7 feet above ground.

Table 3-5. Breaching charges for reinforced concrete

Concrete Thickness (Feet)	Placement Methods				
					
	C = 1.0	C = 1.0	C = 1.8	C = 2.0	C = 3.6
	Packages of M112 (Composition C4)				
2.0	1	5	9	10	17
2.5	2	9	17	18	33
3.0	2	13	24	26	47
3.5	4	21	37	41	74
4.0	5	31	56	62	111
4.5	7	44	79	88	157
5.0	9	48	85	95	170
5.5	12	63	113	126	226
6.0	13	82	147	163	293
6.5	17	104	186	207	372
7.0	21	111	200	222	399
7.5	26	137	245	273	490
8.0	31	166	298	331	595

NOTE: The results of all calculations for this table have been rounded UP to the next whole package.

3-14. Breaching Other Materials. You can also use Table 3-5 to determine the amount of C4 required for other materials by multiplying the value from the table by the proper conversion factor from Table 3-6. Use the following procedure:

a. Determine the type of material in the target. If in doubt,

assume the material to be the strongest type from the same category.

b. Determine from Table 3-5 the amount of explosive required if the object were made of reinforced concrete.

c. Find the appropriate conversion factor from Table 3-6.

d. Multiply the number of packages of explosive required (from Table 3-5) by the conversion factor (from Table 3-6).

Table 3-6. Conversion factors for material other than reinforced concrete

Material	Conversion Factor
Earth	0.1
Ordinary masonry Hardpan Shale Ordinary concrete Rock Good timber Earth construction	0.5
Dense concrete First-class masonry	0.7

3-15. Number and Placement of Charges.

a. Number of Charges. Use the following formula for determining the number of charges required for demolishing piers, slabs, or walls:

$$N = \frac{W}{2R}$$

where–

N = number of charges. (If N is less than 1.25, use one charge; if N is 1.25 but less than 2.5, use two charges; if N is equal to or greater than 2.5, round to the nearest whole number and use that many charges.)

W = pier, slab, or wall width, in feet.

R = breaching radius, in feet.

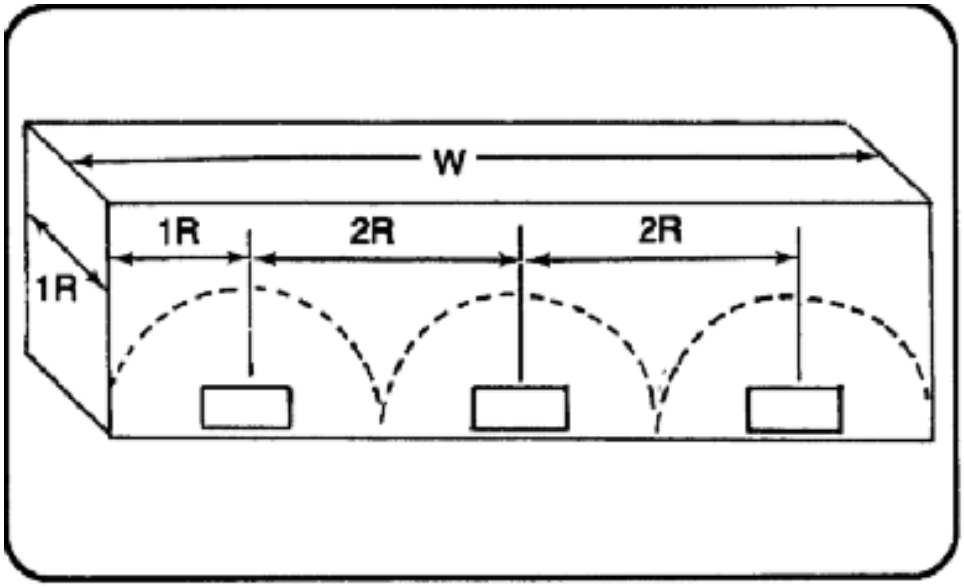


Figure 3-16. Charge placement

The first charge is placed R distance in from one side of the target. The remainder

of the charges are spaced at a distance of 2R apart (Figure 3-16).

b. Placement.

(1) Limitations. Piers and walls offer limited locations for placing explosives.

Unless a demolition chamber is available, place the

charge (or charges) against one face of the target. Placing a charge above ground level is more effective than placing one directly on the ground. When the demolition requires several charges to destroy a pier, slab, or wall and you plan to use elevated charges, distribute the charges equally, no less than one breaching radius high from the base of the target.

Doing this takes maximum advantage of the shock wave. If possible, place breaching charges so that there is a free reflection surface on the opposite side of the target. This free reflection surface allows spalling to occur. If time permits, tamp all charges thoroughly with soil or filled sandbags.

The tamped area must be equal to or greater than the breaching radius. For piers, slabs, or walls partially submerged in water, place charges equal to or greater than the breaching radius below the water line, if possible (Figure 3-15, page 3-16).

(2) Configuration. For maximum effectiveness, place the explosive charge in the shape of a flat square. The charge width should be approximately three times the charge thickness. The thickness of the charge depends on the amount of explosive required (Table 3-7).

Table 3-7. Breaching charge thickness*

Charge Weight (Pounds)	Charge Thickness (Inches)
Less than 5	1
5 to less than 40	2
40 to less than 300	4
300 or more	8
*Approximate values	

3-16. Counterforce Charge.

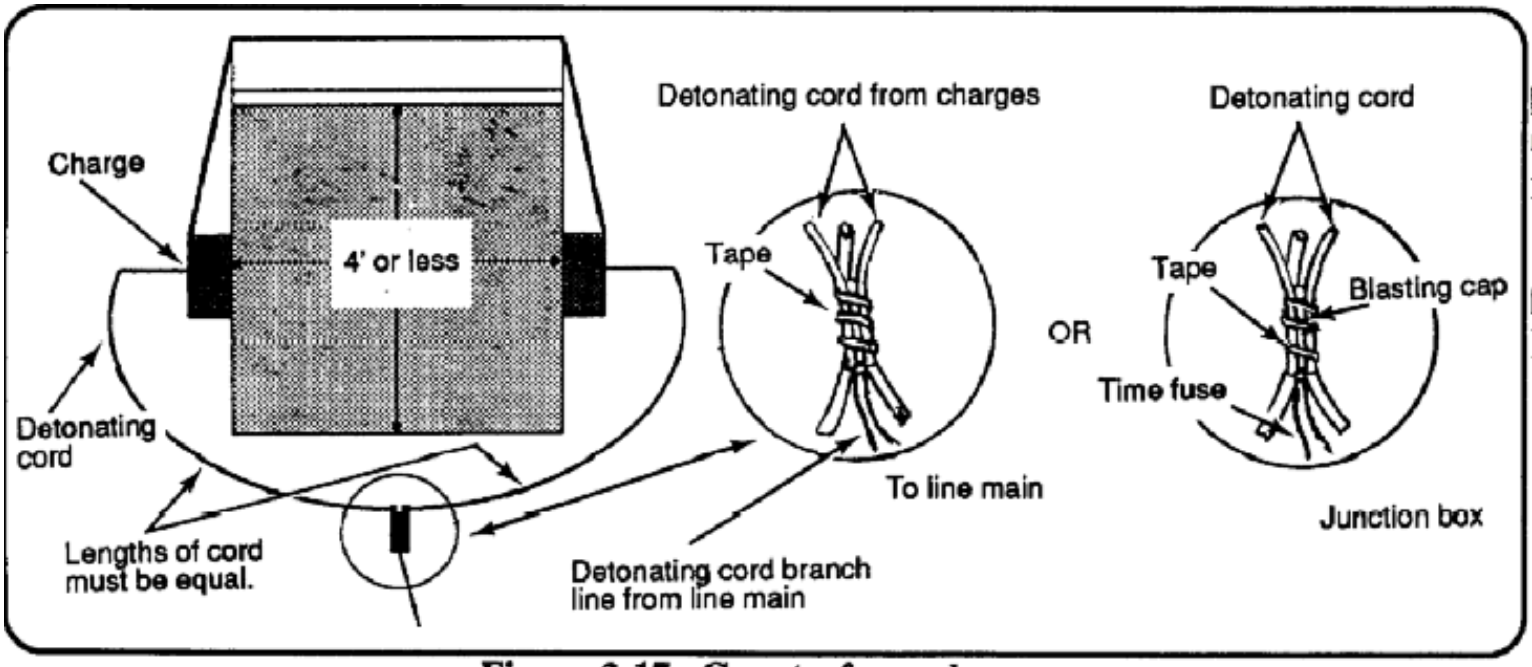


Figure 3-17. Counterforce charge

a. Use. This special breaching technique is effective against rectangular masonry or concrete columns 4 feet thick or less. It is not effective against walls, piers, or long obstacles. The obstacle also must have at least three free faces or be freestanding. If constructed of plastic explosives (C4) and properly placed and detonated, counterforce charges produce excellent results with a relatively small amount of explosive. Their effectiveness results from the simultaneous detonation of two charges placed directly opposite each other and as near the center

of the target as possible (Figure 3-17).

b. Calculation. The thickness or diameter of the target determines the amount of plastic explosive required. The amount of plastic explosive equals 1½ times the thickness of the target, in feet (1 ½ pounds of explosive per feet). Round fractional measurements to the next higher half foot before multiplying. For example, a concrete target measuring 3 feet 9 inches thick requires 6 pounds of plastic explosive (1.5 lb/foot x 4 feet).

c. Placement. Split the charge in half. Place the two halves directly opposite each other on the target. This method requires accessibility to both sides of the target so the charges will fit flush against their respective target sides.

d. Priming. Prime both charges on the face farthest from the target. Join the ends of the detonating-cord branch lines in a junction box (Figure 3- 17). The length of the branch lines from both charges must be equal to ensure simultaneous detonation.

Section V. Cratering and Ditching Charges

3-17. Factors.

a. Sizes. To be effective obstacles, road craters must be too wide for track vehicles to span and too deep and steep-sided for any vehicle to pass through. Blasted road craters will not stop modern tanks indefinitely. A tank, making repeated attempts to traverse the crater, will pull soil loose

from the slopes of the crater, filling the bottom and reducing both the crater's depth and angle of slope.

Road craters are effective antitank obstacles if a tank requires three or more passes to traverse the

crater, thereby providing enough time for antitank weapons to stop the tank. Road craters should

be large enough to tie into natural or constructed obstacles at each end. Improve the effectiveness of blasted road craters by placing log hurdles on either side, digging the face of the hurdle vertically on the friendly side, mining the site with antitank and antipersonnel mines, filling the crater with water, or by using other means to further delay enemy armor. Cut road craters across the desired gap at a 45-degree angle from the direction of approach. This angled cut will increase the tank's tendency to slip sideways and ride off its track. To achieve sufficient obstacle depth, place craters in multiple or single rows, enhancing some other obstacle, such as a bridge demolition. When creating more than one row of craters, space them far enough apart so that a single armored vehicle launch bridge (AVLB) will not span them.

b. Explosives. All military explosives can create antitank craters. When available, use the 40-pound, ammonium-nitrate cratering charge (Figure 1-5, page 1-8) for blasting craters.

c. Charge Confinement. Place cratering charges in

boreholes and tamp them.

3-18. Breaching Hard-Surfaced Pavements. Breach hard-surfaced pavements so that holes can be dug for the cratering charges. This can be done by exploding tamped charges on the pavement surface. Use a l-pound charge of explosive for each 2 inches of pavement thickness. Tamp the charges twice as deep as the pavement thickness. Shaped charges also are effective for breaching hard-surfaced pavements. A shaped charge will readily blast a small-diameter borehole through the pavement and into the subgrade. Blasting the boreholes with shaped charges will speed up the cratering task by first, eliminating the need to breach the pavement with explosive charges and then digging the hole for the cratering charge. Do not breach concrete at an expansion joint because the concrete will shatter irregularly. Table 1-3 (page 1-10) lists hole depths and optimum standoff distances when using the 15- or 40-pound shaped charges against various types of material, Shaped charges do not always produce open boreholes capable of accepting a 7-inch diameter cratering charge. You may need to remove some earth or widen narrow areas to accommodate the cratering charge. Widen deep, narrow boreholes by knocking material from the constricted areas with a pole or rod or by breaking off the shattered concrete on the surface with a pick or crowbar.

3-19. Hasty Crater. This method takes the least amount of time to construct, based upon the number and depth of

the boreholes. However, it produces the least effective barrier because of its depth and shape (Figure 3-18).

The hasty method forms a V-shaped crater about 6 to 7 feet deep and 20 to 25 feet wide, extending approximately 8 feet beyond each end borehole. The sides of the crater slope 25 to 35 degrees. Modern US tanks require an average of four attempts to breach a hasty crater. To form a crater that is effective against tanks, boreholes must be at least 5 feet deep with at least 50 pounds of explosive in each hole. Use the following procedure to create a road crater:

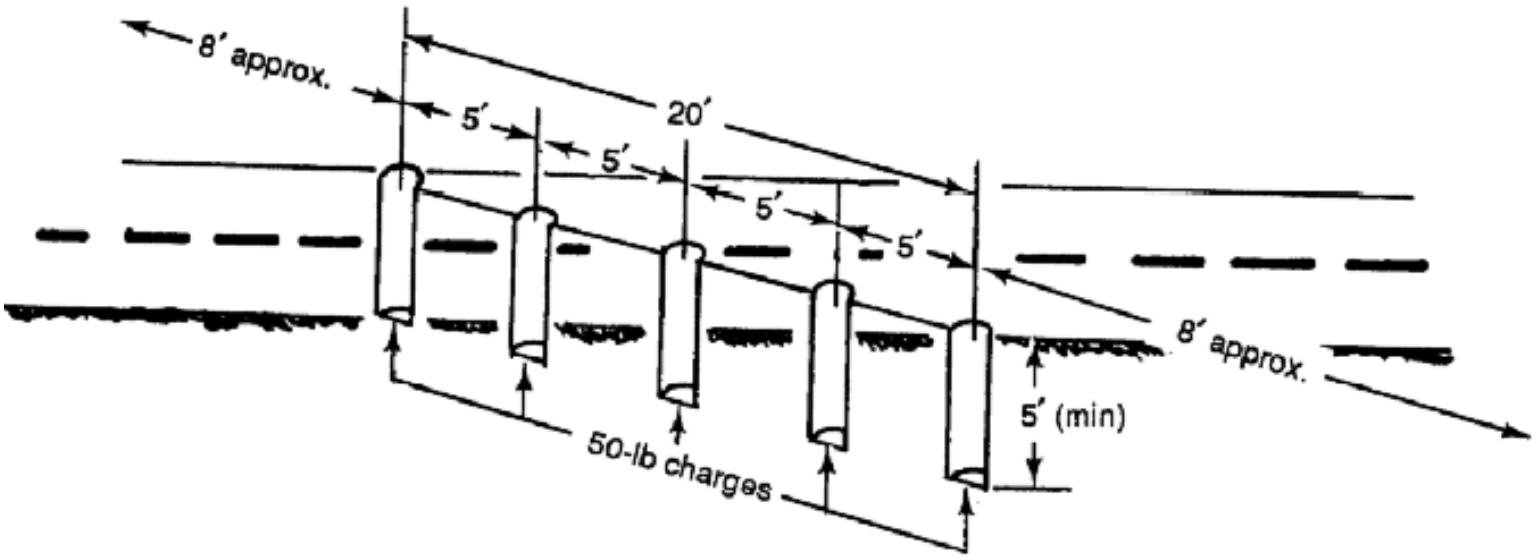


Figure 3-18. Placing charges for a hasty crater

a. Boreholes. Dig all boreholes to the same depth (5 feet or deeper recommended). Space the boreholes at 5-foot intervals, center to center, across the road. Use the following formula to compute the number of boreholes:

$$N = \frac{L - 16}{5} + 1$$

where–

N = number of boreholes; round fractional numbers to next higher whole number.

L = length of the crater, in feet. (Measure across the area to be cut. Round fractional measurements to the next higher foot).

16 = combined blowout of 8 feet each side.

5 =5-foot spacing.

1 = factor to convert from spaces to holes.

b. Charge Size. Load the boreholes with 10 pounds of explosive per foot of borehole depth.

When using standard cratering charges, supplement each charge with additional explosives to obtain the required amount. For example, a 6-foot hole would require one 40-pound cratering charge and

20 pounds of TNT or C4.

c. Firing System. Use dual firing systems when time and explosives permit (Figures 2-27, page 2-24). Initiate with either electric or nonelectric caps. Dual prime the 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

d. Tamping. Tamp all boreholes with suitable materials.

3-20. Deliberate Crater. Figure 3-19 illustrates a method that produces a more effective crater than the hasty method.

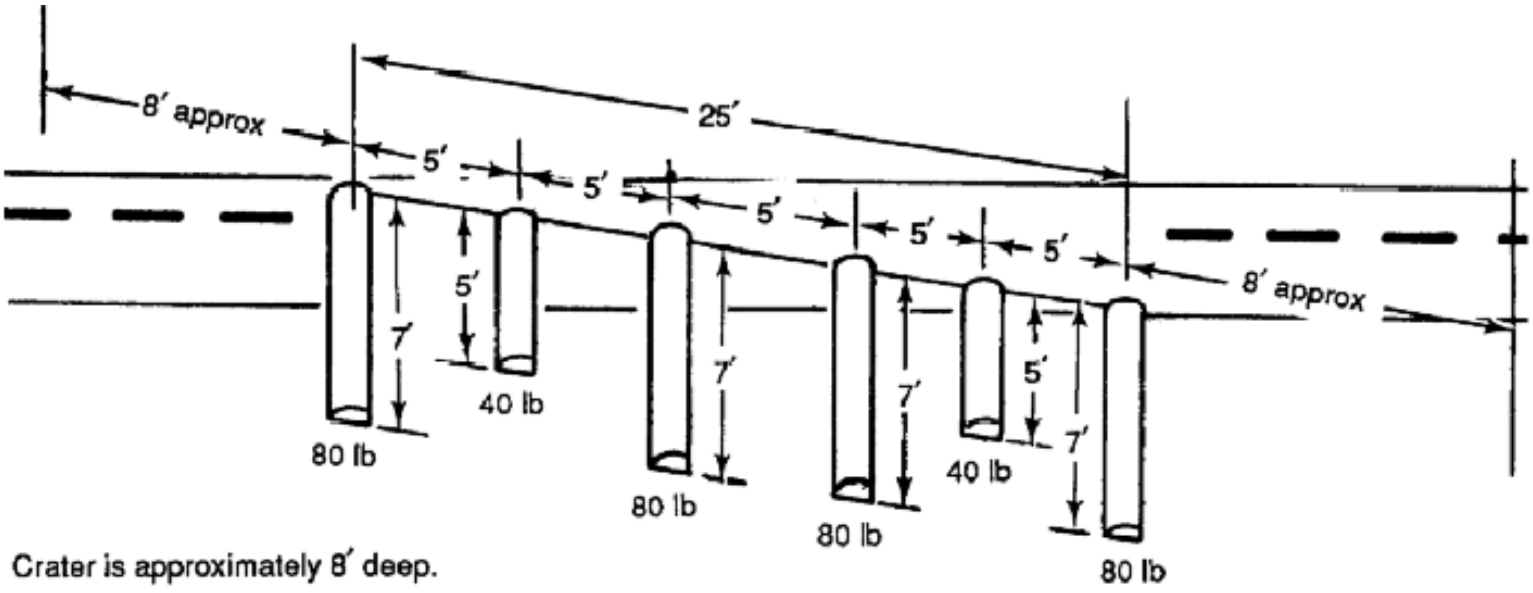


Figure 3-19. Placing charges for a deliberate crater

Modem US tanks require an average of eight attempts to breach a deliberate crater. Placing charges deliberately produces a V-shaped crater, approximately 7 to 8 feet deep and 25 to 30 feet wide, with side slopes of 30 to 37 degrees. The crater extends approximately 8 feet beyond the end boreholes. Example A-11 (page A-9) shows how to calculate a cratering charge.

a. Determine the number of boreholes required, using the same formula as for a hasty crater.

When there is an even number of holes (Figure 3-20, page 3-24), place two adjacent 7-foot boreholes in the middle.

b. Dig or blast the boreholes 5 feet apart, center to center, in a line across the area to be cut.

Make the end boreholes 7 feet deep and the other boreholes alternately 5 and 7 feet deep. Never place two 5-foot holes next to each other.

c. Place 80 pounds of explosive in the 7-foot holes and 40 pounds of explosive in the 5-foot holes.

d. Use dual firing systems (Figure 2-27, page 2-24). Initiate with either electric or nonelectric caps. Dual prime the 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

e. Tamp all charges with suitable materials.

3-21. Relieved-Face Crater. The method shown in Figure 3-20 (page 3-24) produces a crater that is a more effective obstacle to modern tanks than the standard V-shaped crater. This technique produces a trapezoidal-shaped crater about 7 to 8 feet deep and 25 to 30 feet wide with unequal side slopes. In compact soil, such as clay, the relieved-face cratering method will create an obstacle such as the one illustrated in Figure 3-20 (page 3-24). The side nearest the enemy slopes approximately 25 degrees from road surface to crater bottom. The opposite (friendly) side slopes approximately 30 to 40 degrees from road surface to crater bottom. However, the exact shape of the crater depends on the type of soil. Use the following procedure to create a relieved-face crater:

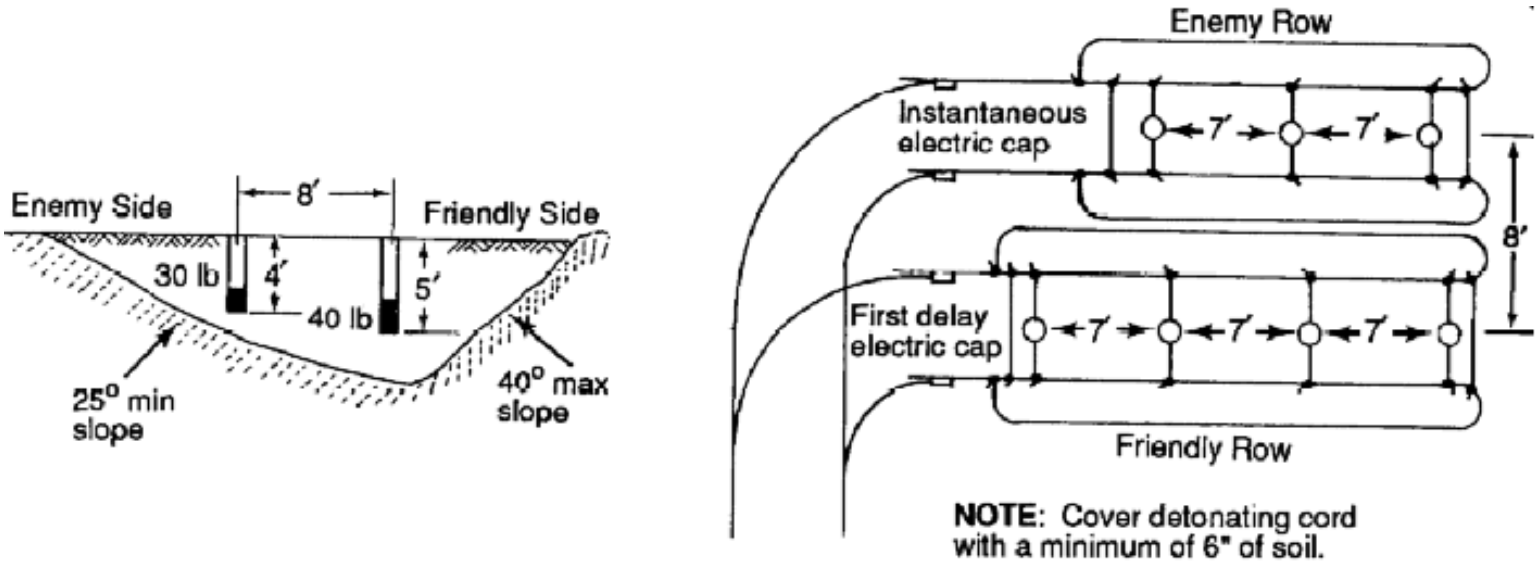


Figure 3-20. Relieved-face crater

a. On dirt or gravel-surfaced roads, drill two lines of boreholes 8 feet apart, spacing them at 7-foot centers. On hard-surfaced roads, drill the two lines of boreholes 12 feet apart. Use the following formula to compute the number of boreholes for the friendly-side row:

$$N = \frac{L - 10}{7} + 1$$

where—

N = number of boreholes; round fractional numbers to the next higher whole number.

L = crater length, in feet. (Measure across the area to be cut. Round fractional measurements to the next higher foot.)

10 = combined blowout of 5 feet each side.

7 = spacing of holes.

1 = factor to convert spaces to holes.

b. Stagger the boreholes in the row on the enemy side in relation to the holes in the row on the friendly side (Figure 3-20). The line closest to the enemy will always contain one less borehole than the friendly line.

c. Make the boreholes on the friendly side 5 feet deep, and load them with 40 pounds of explosive. Make the boreholes on the enemy side 4 feet deep, and load them with 30 pounds of explosive.

d. Use a dual firing system for each line of boreholes. Prime any 40-pound cratering charge as shown in Figure 2-21 (page 2-20).

e. Tamp all holes with suitable material.

There must be a 0.5- to 1.5-second delay in detonation between the two rows of boreholes.

Detonate the row on the enemy side frost. Then fire the friendly-side row while the earth from the enemy-side detonation is still in the air. Use standard delay caps. If the firings cannot be staggered, fire both rows simultaneously. However, the crater produced by a simultaneous detonation will not have the same depth and trapezoidal shape as a relieved-face crater.

3-22. Misfire Prevention. The shock and blast of the first row of charges may affect the delayed detonation of the

friendly-side charges. To prevent misfires of the friendly-side charges, protect its detonating-cord lines by covering them with approximately 6 inches of earth.

3-23. Creating Craters in Permafrost and Ice.

a. Blasting in Permafrost. Permafrost can be as hard as solid rock. Therefore, you must adapt the procedures for blasting or cratering to accommodate permafrost conditions. In permafrost, blasting requires approximately twice as many boreholes and larger charges than for cratering operations in moderate climates. Blasted, frozen soil breaks into clods 12 to 18 inches thick and 6 to 8 inches in diameter. Because normal charges have insufficient force to blow these clods clear of the boreholes, the span falls back into the crater when the blast subsides.

(1) Boreholes. Before conducting extensive blasting, perform a test on the soil in the area to determine the number of boreholes needed. Dig the boreholes with standard drilling equipment, steam-point drilling equipment, or shaped charges. Standard drilling equipment has one serious defect—the air holes in the drill bits freeze. There is no known method to prevent this freezing.

Steam-point drilling is effective for drilling boreholes in sand, silt, or clay, but not in gravel. Place the charges immediately after withdrawing the steam point; otherwise,

the area around the borehole thaws and collapses. Shaped charges also are effective for producing boreholes, especially when forming craters. Table 1-3 (page 1-10) lists borehole sizes made by shaped charges in permafrost and ice.

(2) Explosives. If available, use low-velocity explosives, such as ammonium nitrate, for blasting holes in arctic climates. The displacing quality of low-velocity explosives will more effectively clear large boulders from the crater. If only high-velocity explosives are available, tamp the charges with water and let them freeze before detonating. Unless thoroughly tamped, high-velocity explosives tend to blow out of the boreholes.

b. Blasting in Ice. Access holes in ice are required for obtaining water and determining the capacity of the ice for bearing aircraft and vehicles. To accommodate rapid forward movements, you must be capable of quickly determining ice capacities. Blasting operations provide this ability.

(1) Boreholes. Make small-diameter access holes using shaped charges. The M2A4 charge will penetrate ice as thick as 7 feet; the M3A1 charge will penetrate over 12 feet of ice (Table 1-3, page 1-10). The M3A1 can penetrate deeper, but it has only been tested on ice approximately 12 feet thick. If placed at the normal standoff distance, the charge forms a large crater at the surface, requiring you to do considerable probing to find

the actual borehole. Use a standoff distance of 42 inches or more with the M2A4 shaped charge to avoid excessive crater formation. The M2A4 creates an average borehole diameter of 3 ½ inches. An M3A1 borehole has an average diameter of 6 inches. In late winter, ice grows weaker and changes color from blue to white. Although the structure and strength of ice vary, the crater effect is similar, regardless of the standoff distance.

(2)

Craters. Make surface craters with ammonium-nitrate cratering charges or demolition blocks.

For the best results, place the charges on the surface of cleared ice and tamp them with snow. When determining charge size, keep in mind that ice has a tendency to shatter more readily than soil, and this tendency will decrease the charge's size.

c. Making Vehicle Obstacles. Create a vehicle obstacle in ice by first making two or more rows of boreholes. Space the boreholes 9 feet apart and stagger them in relation to the holes in the other rows. Suspend MI12 charges about 2 feet below the bottom surface of the ice with cords tied to sticks, bridging the sticks over the top of the holes. The size of the charge depends on the thickness and condition of the ice. Use test shots to find the optimum amount. This type of obstacle can retard or halt enemy vehicles for approximately 24 hours at temperatures near -24 degrees

Fahrenheit.

3-24. Craters as Culverts. Destroying a culvert not more than 15 feet deep may also produce an effective crater. Prime the charges for simultaneous detonation, and thoroughly tamp all charges with sandbags. Destroy culverts that are no deeper than 5 feet by placing explosive charges in the same way as for hasty road craters. Space the boreholes at 5-foot intervals in the fill above and alongside the culvert. In each hole place 10 pounds of explosives per foot of depth 3-25. Craters as Antitank Ditches. Excavate antitank ditches by either the hasty or deliberate cratering method (paragraphs 3-19 and 3-20, pages 3-22 and 3-23).

3-26. Ditching Methods. Explosives can create ditches rapidly. Slope ditches at a rate of 2 to 4 feet of depth per 100 feet of run. Place ditches in areas where natural erosion will aid in producing the correct grade. If you cannot place a ditch in an area aided by erosion, make the ditch deeper, increasing the depth as the length increases. Use the following methods for creating ditches:

a. Single Line. The single-line method (Figure 3-21) is the most common ditching method.

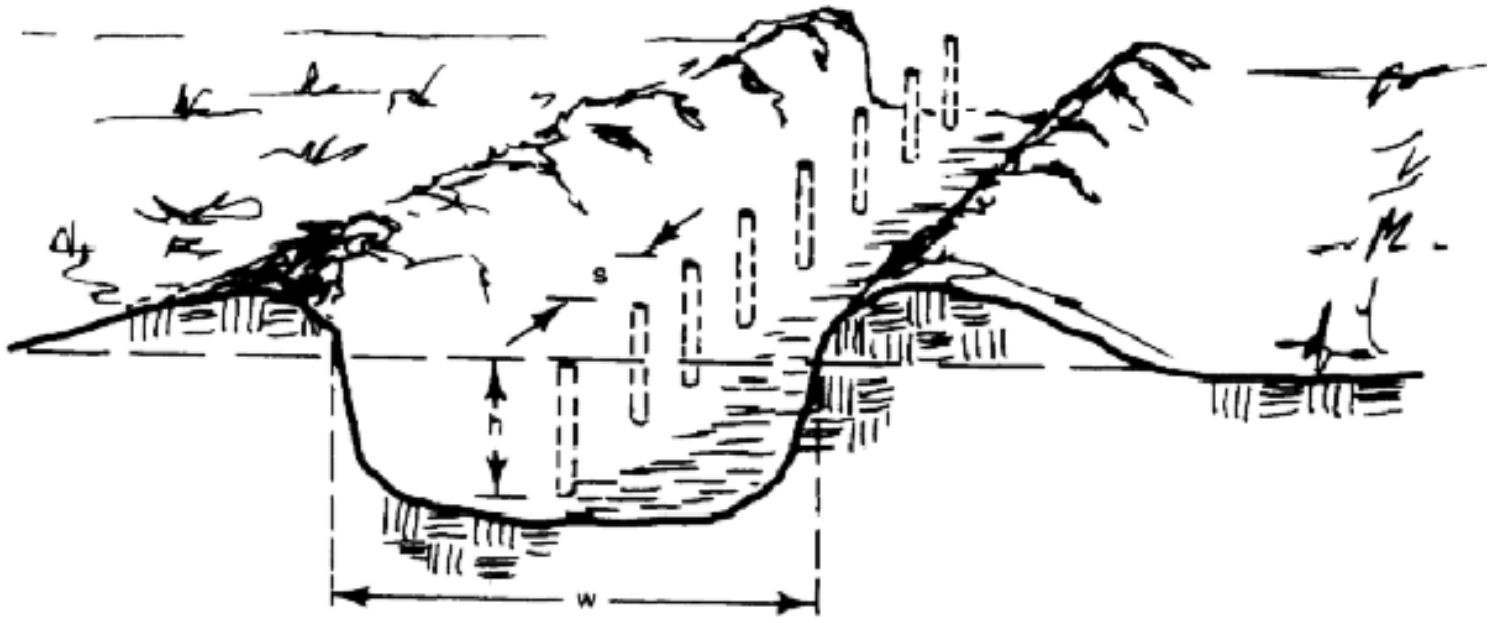


Figure 3-21. Single-line method of ditching

Table 3-8. Single-line ditching explosives data

Serial	Required Ditch Depth (*d*)	Required Width Top of Ditch (*w*) (Feet)	Charges per Hole (Pounds)	Borehole Depth (*h*) (Feet)	Borehole Spacing (*s*) (Feet)
a	b	c	d	e	f
1	2.5	5.0	0.5	1.5	1.5
2	3.0	7.0	1.0	2.0	2.0
3	4.0	9.0	2.0	3.0	3.0
4	6.0	12.0	5.0	5.0	4.0
5	10.0	16.0	10.0	8.0	5.0

Detonate a single row of charges along the centerline of the proposed ditch, leaving any further widening for subsequent lines of charges. Table 3-8 gives charge configurations for the single-line method.

b. Cross Section. When it is necessary to blast the full width of the ditch in one operation, use the cross-section

method (Figure 3-22). Table 3-9 gives charge configurations for the cross-section method. Place an extra charge midway between lines of charges.

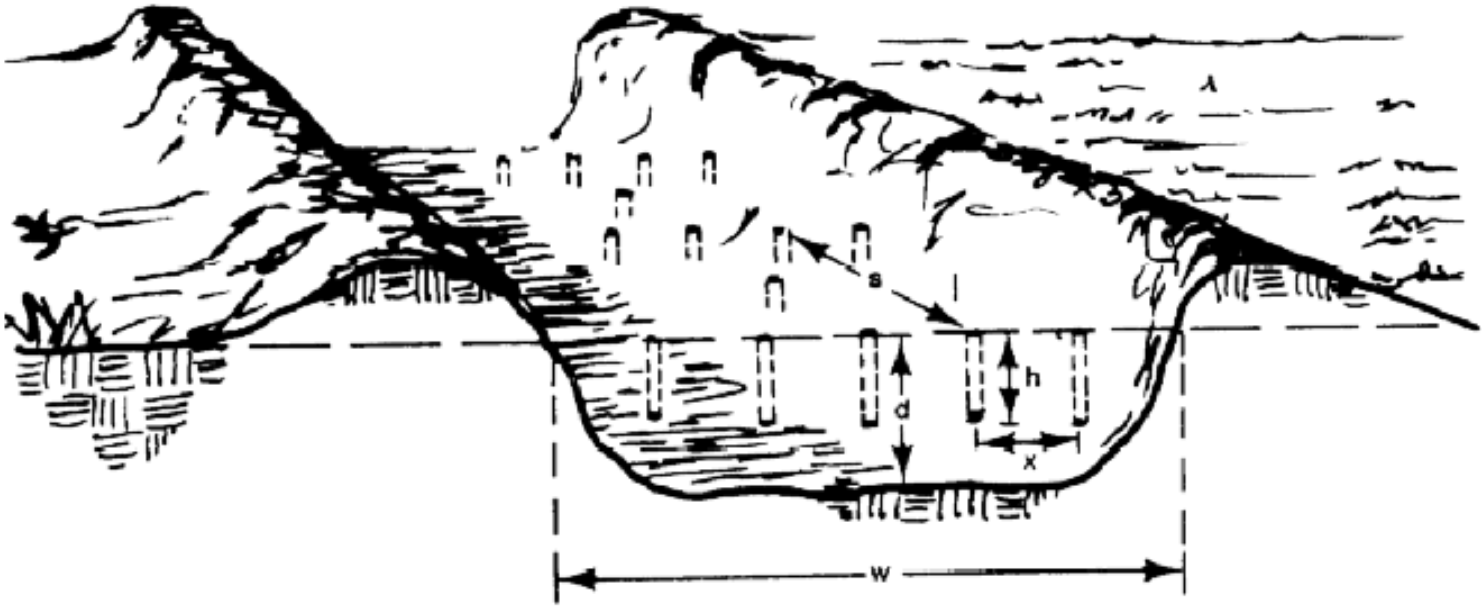


Figure 3-22. Cross-section method of ditching

Table 3-9. Cross-section ditching explosives data

Serial	Required Depth (*d*)	Required Width (*w*) in Feet — Number of Boreholes in Each Cross Section					Charge per Hole (Pounds)	Borehole Depth (*h*) (Feet)	Borehole Spacing (*s*) (Feet)	Row Spacing (x) (Feet)
		3	5	7	9	11				
a	b	c	d	e	f	g	h	I	j	k
1	2.5	7.5	11.0	13.0	16.0	18.0	0.5	1.5	1.3	2.5
2	3.0	10.0	13.0	16.0	19.0	22.0	1.0	2.0	1.5	3.0
3	4.0	14.0	19.0	24.0	29.0	34.0	2.0	3.0	2.5	4.5
4	6.0	20.0	28.0	36.0	44.0	52.0	5.0	5.0	4.0	6.0
5	10.0	26.0	33.0	46.0	56.0	65.0	10.0	7.0	5.0	8.0

Section VII. Special Applications

3-31. Survivability Positions. In many circumstances, the use of explosives can reduce digging time and effort. Use explosives only in soil that would normally be excavated

by pick and shovel. Explosives are not recommended for excavations less than 2 feet deep. Use small charges buried and spaced just enough to loosen the soil, limiting the dispersion of soil to as small an area as possible. Do not attempt to form a crater doing this spreads soil over a large area, affecting concealment and weakening the sides of the finished position. Explosives can create individual fighting positions and larger crew-served, gun, or vehicle positions. Using explosives in this manner requires some advance preparation. In the case of an individual fighting position, the preparation time may exceed time required to prepare the position by traditional methods.

a. Depth. Place charges 1 foot shallower than the required depth, to a maximum of 4 feet. If the required depth is greater than 5 feet, dig the position in two stages, dividing the required depth in half for each stage. Make the boreholes with an earth auger, wrecking bar, picket driver, or other expedient device.

b. Spacing. For rectangular excavations, dig the boreholes in staggered lines. For circular excavations, dig the boreholes in staggered, concentric rings. The spacing between boreholes in each line or ring and between lines or rings should be between 1 and 1.5 times the borehole depth.

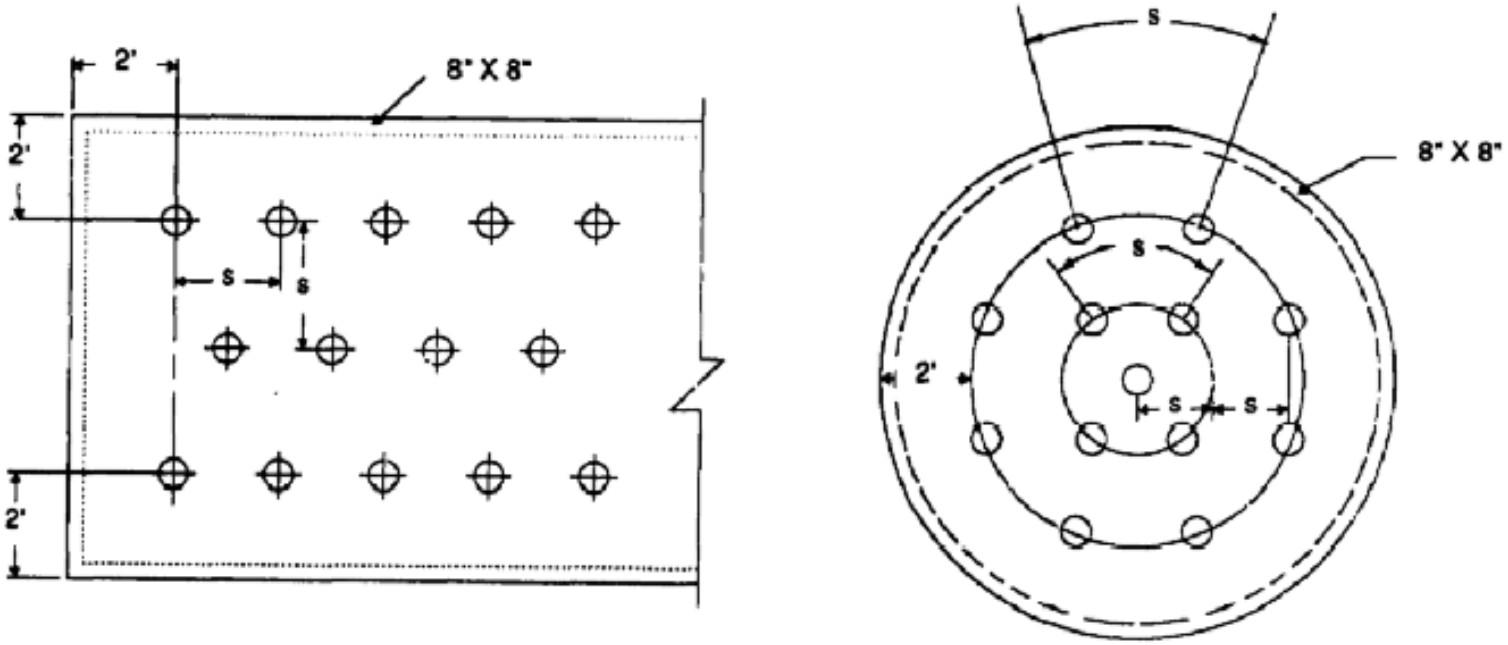


Figure 3-25. Borehole layouts

Ensure all charges are at least 2 feet inside the proposed perimeter of the excavation. Also, dig an 8-by 8-inch channel around the outer perimeter of the proposed excavation, with the outer edge of the channel forming the outer edge of the finished excavation. Figure 3-25 shows layouts for rectangular and circular excavations.

c. Charge Size. Use ¼-pound charges of plastic explosive to dig foxholes. For large excavations, use charges between ½ and 1 ½ pounds, depending on spacing and soil characteristics.

A test shot is usually necessary to determine the correct charge size.

d. Concealment. Reduce explosion noise and spoil scatter by leaving any sod in place and covering the site with a blasting mat. Improvise blasting mats by tying tires together with natural or synthetic rope (steel-wire rope is

unacceptable) or by using a heavy tarpaulin.

3-32. Equipment Destruction.

WARNING

Steel-cutting charges produce metal fragments.

Proper precautions should be taken to protect personnel.

Refer to Table 6-3, page 6-7.

a. Guns. Destroy gun barrels with explosives or their own ammunition. Also be sure to remove or destroy the small components, such as sights and other mechanisms.

(1) Explosive Method.

(a) To prepare a gun for demolition, first block the barrel just above the breach. For small-caliber guns that use combined projectile-propellant munitions, solidly tamp the first meter of the bore with earth. For heavier guns that use projectiles separate from propellants, simply load a projectile and aim the tube to minimize damage should the round be ejected.

(b) Charge Size. Table 3-11 (page 3-32) details the charge size required for standard barrel sizes. If necessary, determine the required charge size using the following formula:

$$P = \frac{D^2}{636}$$

where–

P = quantity of explosive (any high explosive), in pounds.

D = bore size of the barrel, in millimeters.

(c) Placement. Pack the explosive, preferably C4, into the breach, immediately behind the tamping. Place the plastic explosive in close contact with the chamber. Close the breach block as far as possible, leaving only enough space for the detonating cord to pass without being bent or broken. If time permits, place 15-pound charges on the drive wheels of tracked guns and on the wheels and axles of towed guns. Connect the branch lines in a junction box or use a ring main.

Simultaneously detonate all charges.

Table 3-11. Gun-destruction charge sizes

Serial	Barrel Size (Millimeters)	Charge Size (Pounds)
a	b	c
1	76	10
2	105	18
3	120	23
4	155	38
5	203	66

Note: Determine appropriate charge sizes for barrel sizes not listed by comparing them to known barrel sizes. For example, you would use the explosive weight in Serial 3 for a 112-mm barrel (23 pounds); Serial 4 for a 152-mm barrel (38 pounds).

(2) Improvised Method. When block explosives are not available, destroy a gun with its own ammunition. Insert and seat one round in the muzzle end and a second charge, complete with ropellant charge (if required), in the breach end of the tube. Fire the gun from a safe distance, using the gun's own mechanism. Use a long lanyard and ensure the firing party is under cover before firing the gun.

b. Vehicles. To destroy friendly vehicles, refer to the applicable TM. Use the following priorities when destroying vehicle components:

Priority 1. Carburetor, distributor, fuel pump or injectors, and fuel tanks and lines.

Priority 2. Engine block and cooling system.

Priority 3. Tires, tracks, and suspension system.

Priority 4. Mechanical or hydraulic systems (where applicable).

Priority 5. Differentials and transfer case.

Priority 6. Frame.

(1) Armored Fighting Vehicles (AFVs). Destroy AFVs beyond repair by detonating a 25-pound charge inside the hull. The charge may be a bulk 25-pound charge or a number of smaller charges, placed on the driving, turret, and gun controls. To increase the amount of damage to the AFV, ensure the ammunition within the AFV detonates simultaneously with the other charges, and ensure all hatches, weapons slits, and other openings are sealed. If it is not possible to enter the AFV, place the charges under the gun mantle, against the turret ring, and on the final drive (Figure 3-26).

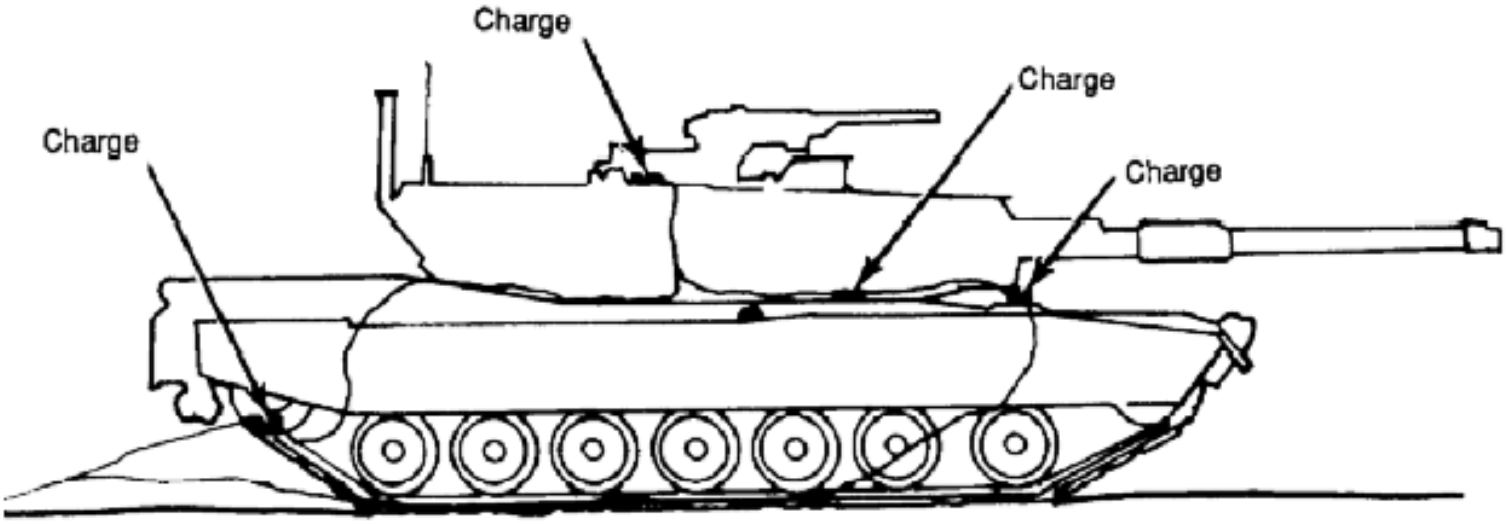


Figure 3-26. Placing charges on the AFV

If explosives are not available, destroy the AFV by using antitank weapons or fire, or destroy the main gun with its own ammunition.

(2) Wheeled Vehicles.

(a) Explosives method. Destroy wheeled vehicles beyond repair by wrecking the vital parts with a sledgehammer or explosives. If high explosives are available, use 2-pound charges to destroy the cylinder head, axles, and frame.

(b) Improvised method. Drain the engine oil and coolant and run the engine at full throttle until it seizes. Finish the destruction by burning the vehicle (ignite the fuel in the tank).

NEXT

BACK TO COMMERCIAL EXPLOSIVES

Chapter 4

Bridge Demolition

Section I. Requirement

4-1. Purpose of Bridge Demolition. The purpose of bridge demolitions is to create gaps in bridges by attacking key components of the bridge. This makes gaps large enough to make repair uneconomical and to force the enemy to construct other bridges on other sites. The minimum gap required must exceed the enemy's assault bridging capability by 5 meters. For planning purposes, use 25 meters as the minimum gap size, but 35 meters is better. The gap may be less than 25 meters if enemy forces must depend on the demolished bridge components to bear their assault bridging and there is insufficient bearing capacity in the remains to carry the loads.

4-2. Degree of Destruction. The complete demolition of a bridge usually involves the destruction of all the components (spans, piers, and abutments). Complete demolition may be justified when the terrain forces the enemy to reconstruct a bridge on the same site. However, complete destruction is not normally required to meet the tactical objective. Select the method of attack that achieves the tactical goal, with a minimum expenditure of resources.

4-3. Debris. Debris may cause enemy forces serious delays if it obstructs the gap (Figure 4-l). Debris also provides excellent concealment for mines and booby traps. Whenever possible, demolish bridges in such a way that the resulting debris hinders reconstruction.

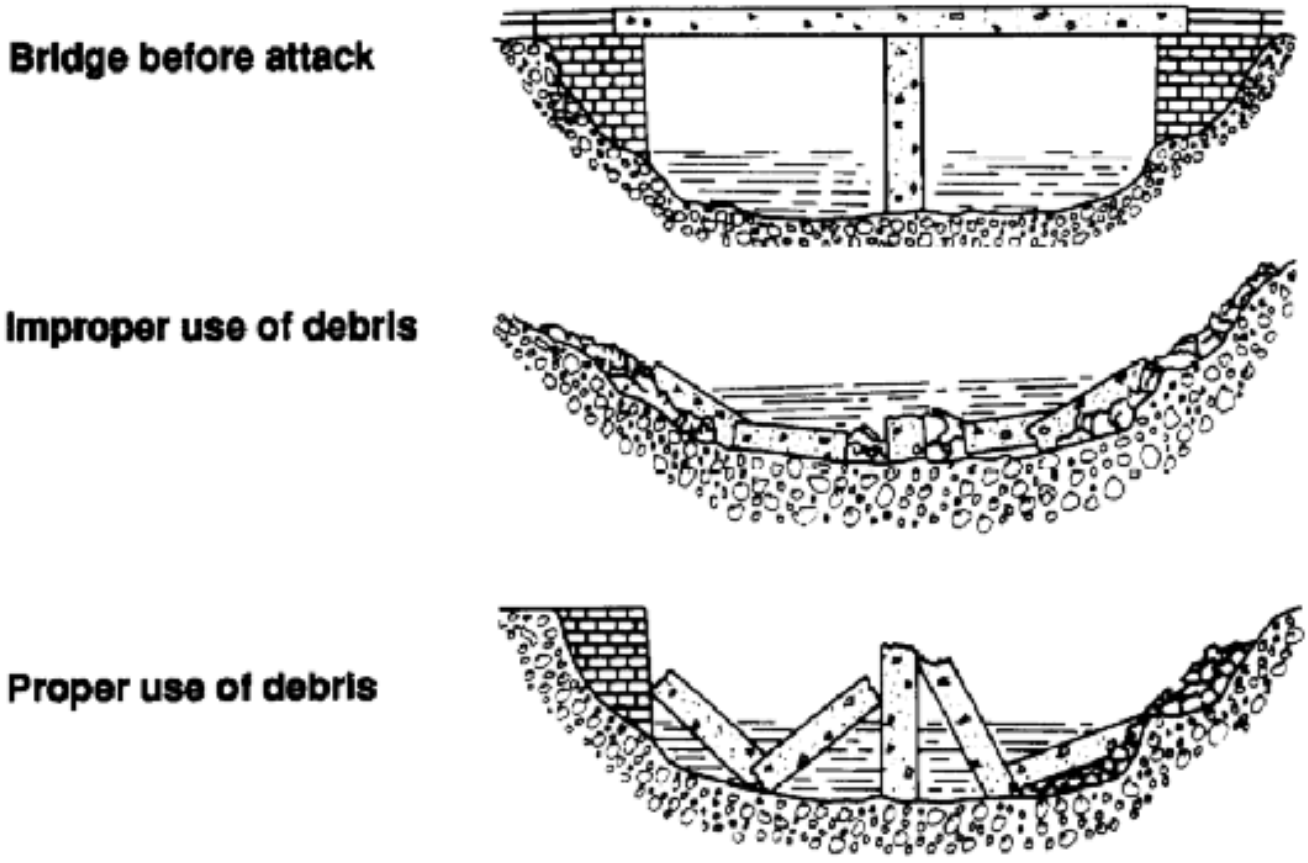


Figure 4-1. Use of debris

Section II. Considerations

4-4. Bridge Categories. The first step in any efficient bridge demolition is to categorize the bridge correctly. The term categorization has been adopted to avoid confusion with classification, which is concerned with the load-carrying capacity of bridges. The correct categorization of bridges, coupled with an elementary knowledge of bridge design, allows you to select a suitable attack method. All

bridges fit into one of three categories:

a. Simply Supported. In simply supported bridges, the ends of each span rest on the supports; there are no intermediate supports. The free-bearing conditions shown in Figure 4-2 represent any bearing that allows some horizontal movement (for example, roller bearings, sliding bearings, and rubber bearing pads).

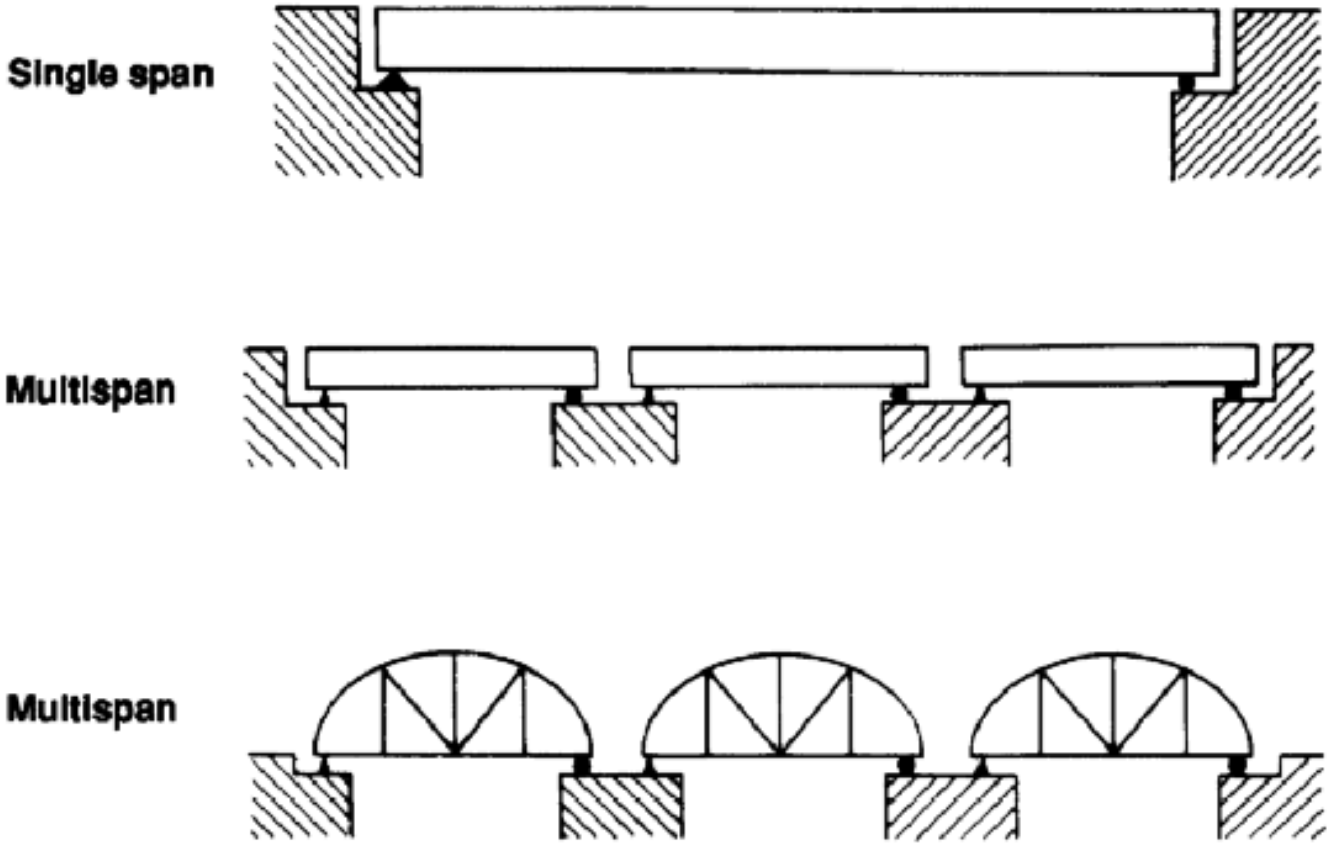


Figure 4-2. Simply supported bridges

b. Miscellaneous. Miscellaneous bridges form a small proportion of bridge structures. The theoretical principles governing these bridges determine the appropriate methods of attack. Examples of bridges in this category are suspension, lift, and cable-stayed bridges.

c. Continuous. If a bridge does not fit the miscellaneous category and is not simply supported, categorize it as a continuous bridge. Hence, continuous has a wider meaning than multispan, continuous-beam bridges, as is normally implied.

4-5. Stages of Destruction. When designing a bridge demolition, the first priority is to create a gap. Accomplishing this may require one or two attacks. Further actions that improve the obstacle may follow, if the situation permits.

a. Minimum Conditions. There are two minimum conditions for successful bridge demolition:

You must design a proper collapse mechanism.

You must ensure the attacked span will be free to move far enough, under its own weight, to create the desired obstacle.

(1) Condition 1. Under normal conditions, a bridge is a stable structure. In bridge demolitions, the goal is to destroy the appropriate parts of a bridge so that it becomes unstable and collapses under its own weight. In other words, you form a collapse mechanism. This may involve either cutting completely through all structural members or creating points of weakness in certain parts of the bridge. Figure 4-3 shows an improper collapse mechanism and the hinges that have not been formed. At times, making bridges unstable by attacking their piers

rather than their superstructures is easier, but it is still possible for bridges not to collapse, even though they lost the support provided by one or more of their piers. To avoid this type of demolition failure, place the charges on the structural members of the superstructure, immediately above the piers being attacked.

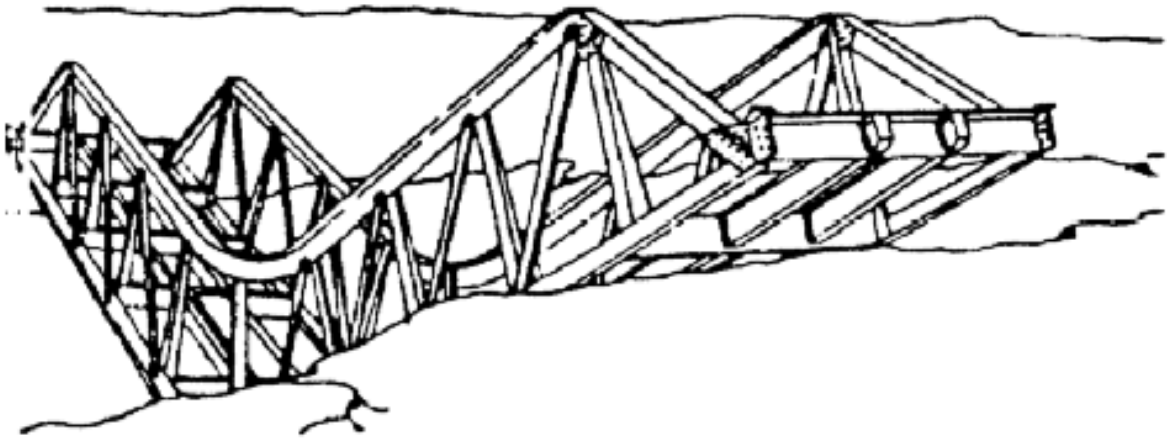


Figure 4-3. Improper collapse mechanism and hinges

(2) Condition 2. Figure 4-4 shows a bridge demolition where the collapse mechanism has formed, but where, because the bridge span has jammed before moving far enough, it has failed to form the desired obstacle. To complete the demolition in this example, you need to remove only a small portion of the abutment to allow the span to swing down freely.

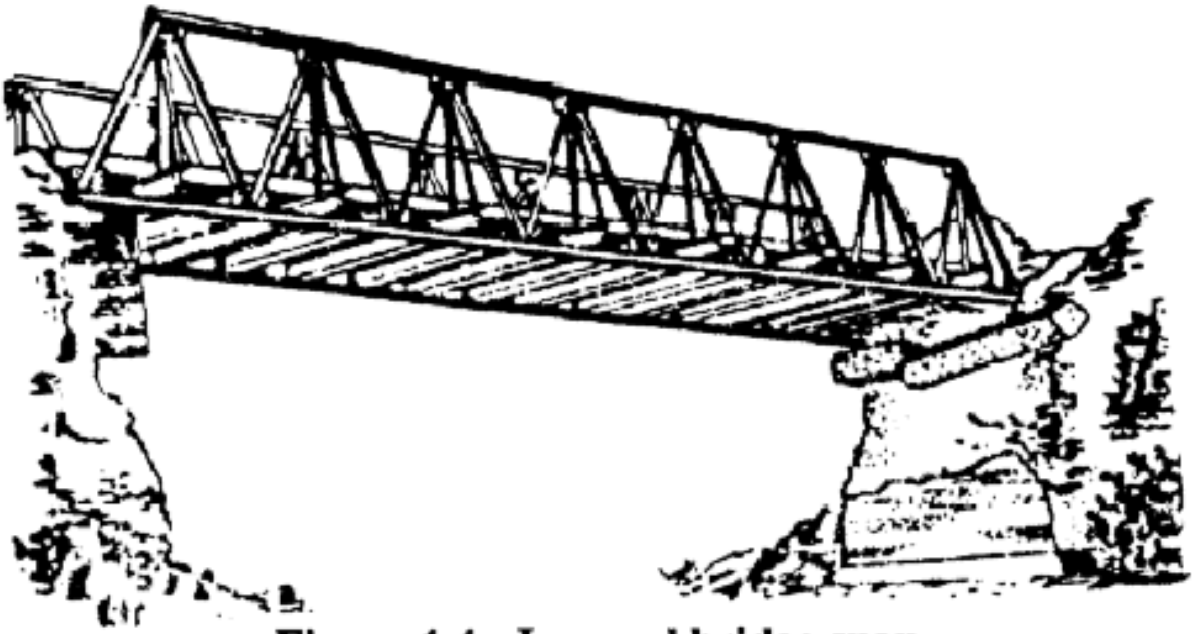


Figure 4-4. Jammed bridge span

b. Types of Collapse Mechanism. Figures 4-5 through 4-7 illustrate the three basic collapse mechanisms.

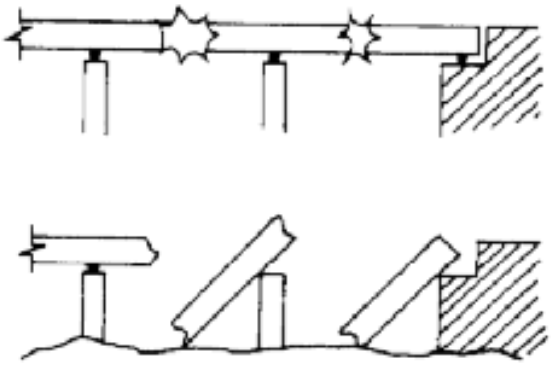


Figure 4-5. See-saw collapse mechanism

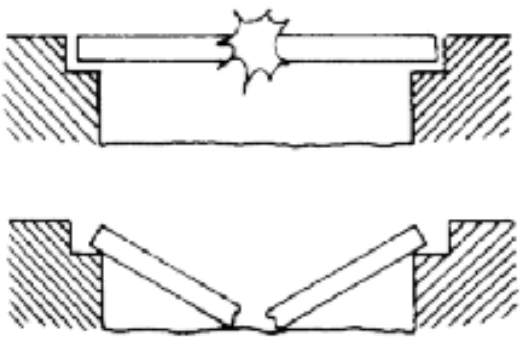


Figure 4-6. Beam collapse mechanism

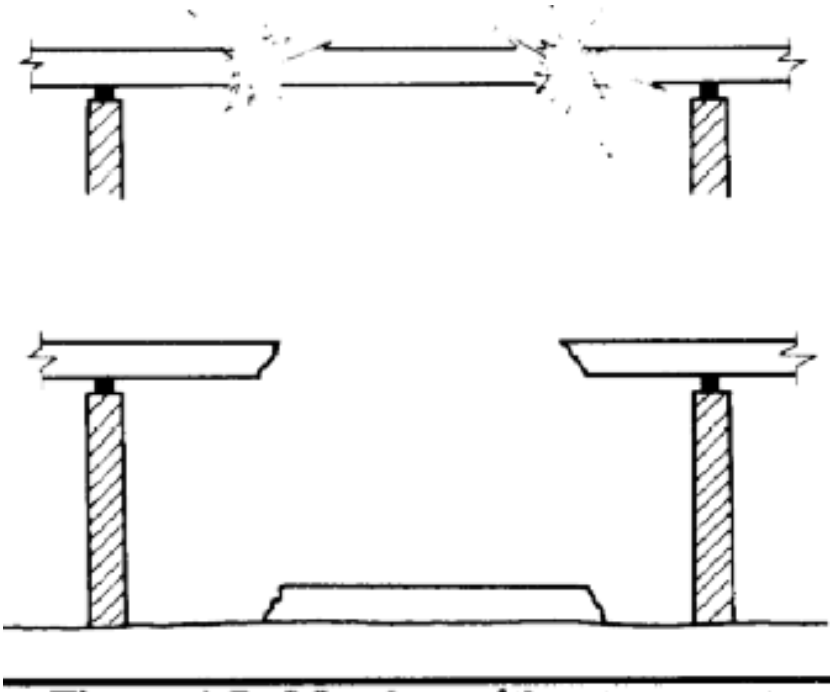


Figure 4-7. Member without support collapse mechanism

c. Unsuccessful Bridge Demolitions.

Two possible reasons for unsuccessful bridge demolitions are—

(1) No-Collapse Mechanism. The formation of cantilevers (Figure 4-8) is a typical example of a no-collapse mechanism being formed. The likelihood of this occurring is high when attacking continuous bridges.

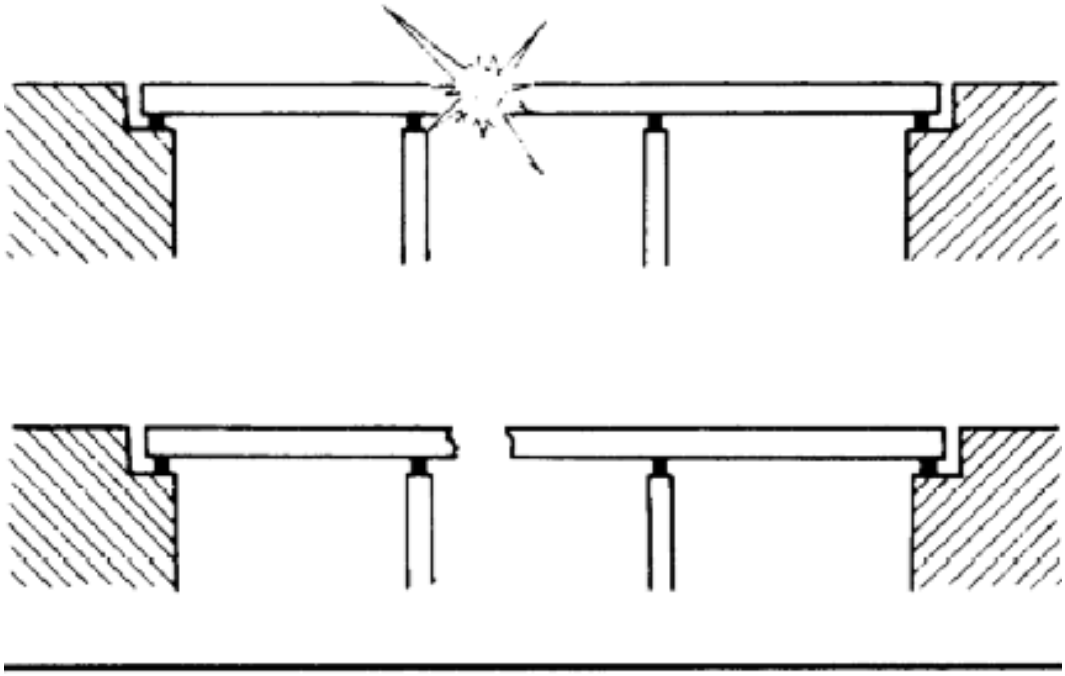


Figure 4-8. Cantilever effect

(2) Jamming. The span, once moved by the collapse mechanism, jams before moving far enough to create the desired obstacle. The most likely causes of jamming are the formation of a three-pin arch or a cranked beam (Figure 4-9). When attacking bridge spans, always consider the possibility of jamming during bottom and top attacks.

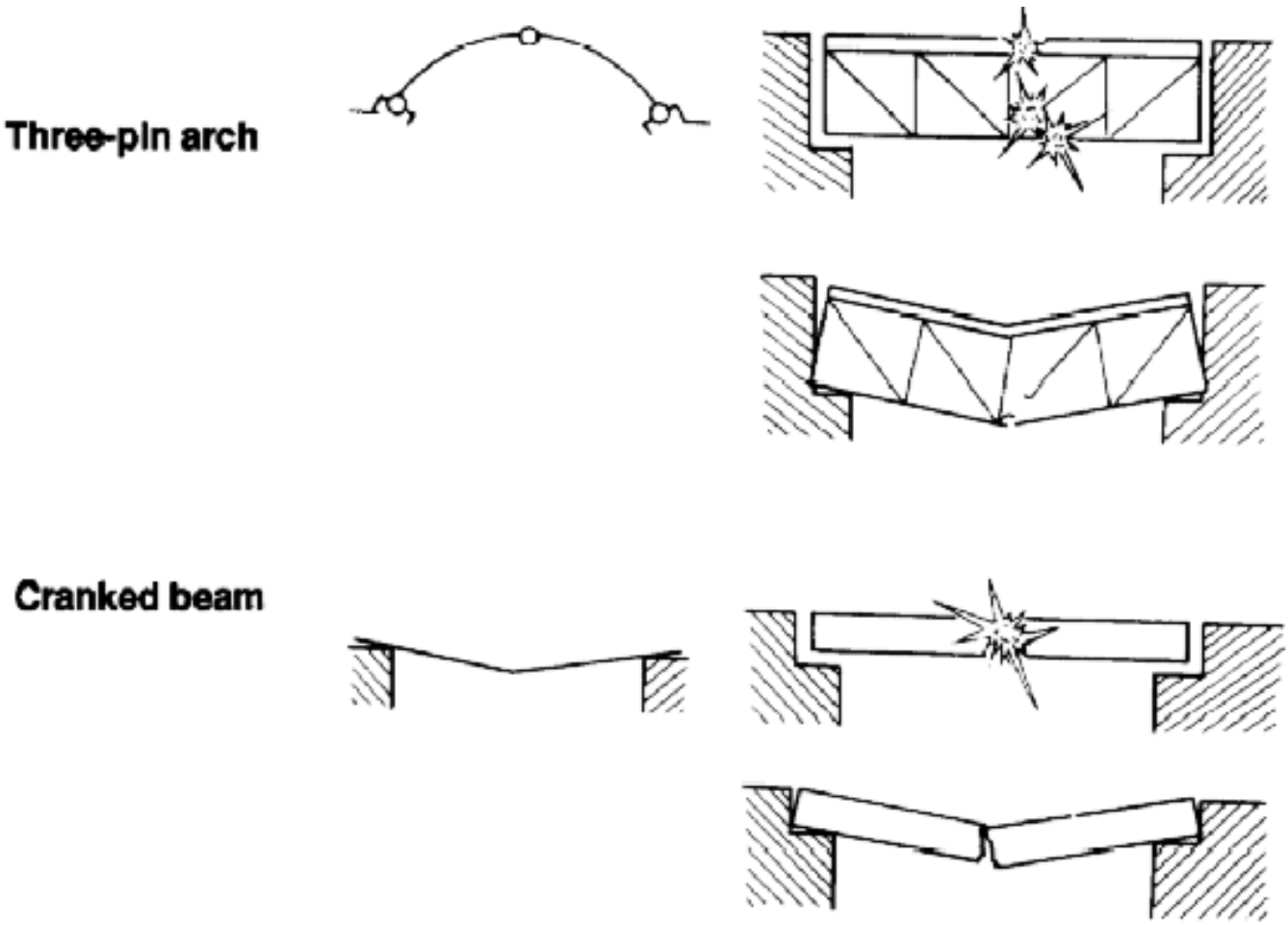


Figure 4-9. Causes of jamming

4-6. Bottom Attack. In the bottom attack, the hinge forms at the top. As the span falls, the cut ends at the bottom move outward. The span may form a three-pin arch and fail to fall completely if the distance the cut ends must move is greater than the total end clearance between the span ends and the pier or abutment faces (Figure 4-10). If a three-pin arch situation is likely, do not attempt a bottom attack.

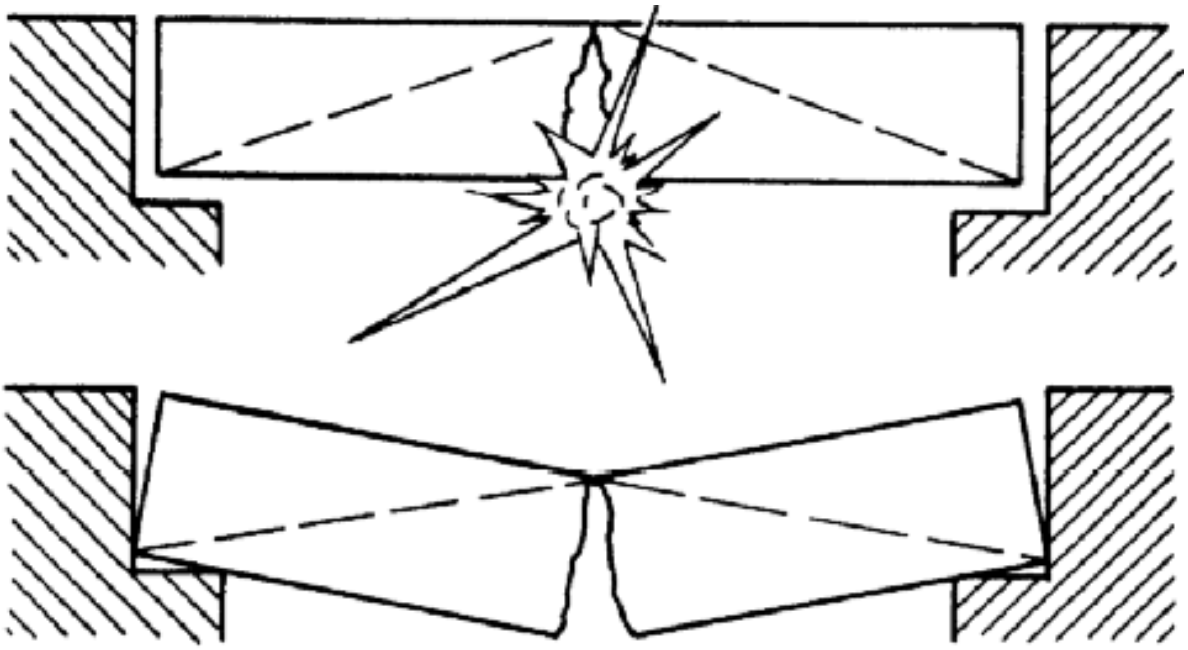


Figure 4-10. Three-pin arch effect

4-7. Top Attack. In a top attack, the hinge forms at the bottom. As the span falls, the cut ends at the top move inward. Some bridges may jam along the faces of the cut before the ends of the span have fallen off the abutments, forming a cranked beam (Figure 4-11).

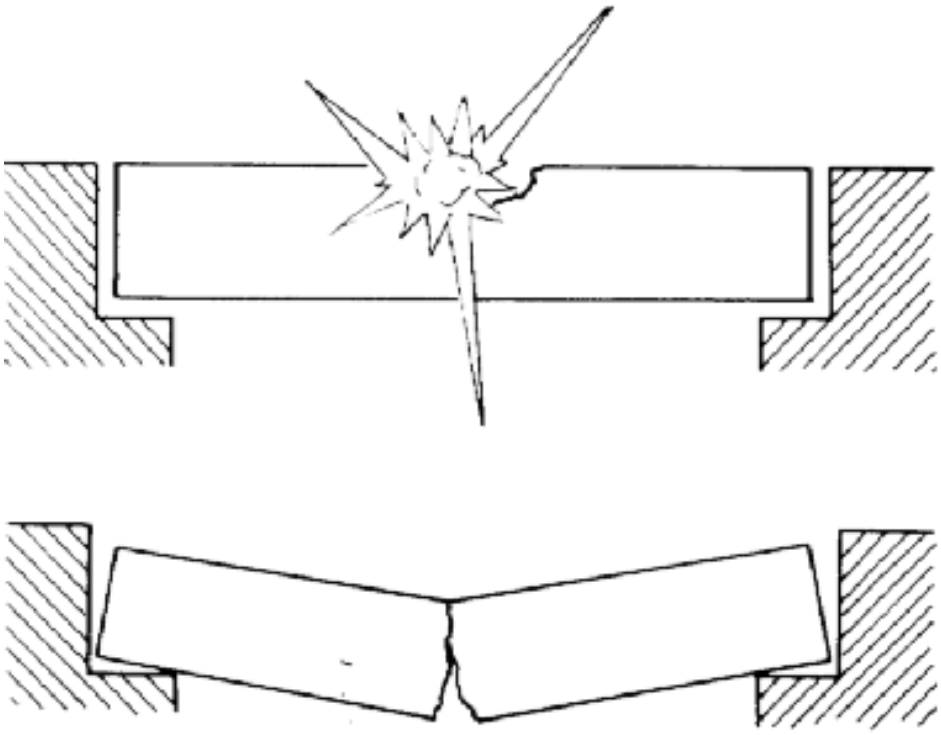


Figure 4-11. Cranked-beam effect

Ensure the length of span removed (LC) at the top is

sufficient to prevent the formation of a cranked beam.

4-8. Efficient Demolition Methods.

To ensure that a demolition achieves collapse with reasonable economy, consider the factors required to achieve an efficient demolition. The best balance between these factors will depend on the particular demolition under consideration. An efficient demolition should—

a. Achieve the desired effect.

b. Use the minimum amount of resources (time, manpower, and explosives).

c. Observe the proper priorities. The demolition reconnaissance report must clearly state the priorities and separately list the requirements for Priority 1 actions and Priority 2 improvements (priorities are explained below). If a sufficient gap will result by attacking bridge spans, do not perform the Priority 2 improvements unless the report specifies complete destruction or an excessively long gap. If the total gap spanned by a bridge is too small to defeat enemy assault bridging, consider the site an unsuitable obstacle unless the gap can be increased. Your engineer effort may be better applied elsewhere. Alternatively, to improve an obstacle, it may be necessary to increase the gap by demolishing the abutments and building craters on the immediate approaches. In this case, you should also attack nearby bypass sites (place mines and craters).

(1) Priority One. Create the desired obstacle. The minimum gap required is 5 meters greater than the enemy's assault bridging capability. Ideally, accomplish the demolition with the first attempt. However, many reinforced- or prestressed-concrete bridges may require two-stage attacks. Attacking the friendly side of spans will permit economical reconstruction of the bridge at a later date, if necessary.

(2) Priority Two. Make improvements to the gap. Perform this activity only when it is specified on the demolition reconnaissance report. When no reconnaissance report has been issued and time permits, perform improvements in the sequence specified below. Deviate from this sequence only under exceptional circumstances or when directed to do so by the responsible commander. The standard sequence of demolition is to-

(a) Destroy and mine the blown abutment

(b) Lay mines in likely bypasses.

(c) Blast craters and lay mines in likely approaches.

(d) Destroy the piers.

4-9. Concrete-Stripping Charges.

a. Description. Concrete-stripping charges are bulk, surface-placed charges designed for removing concrete from reinforced-concrete beams and slabs and exposing

the steel reinforcement.

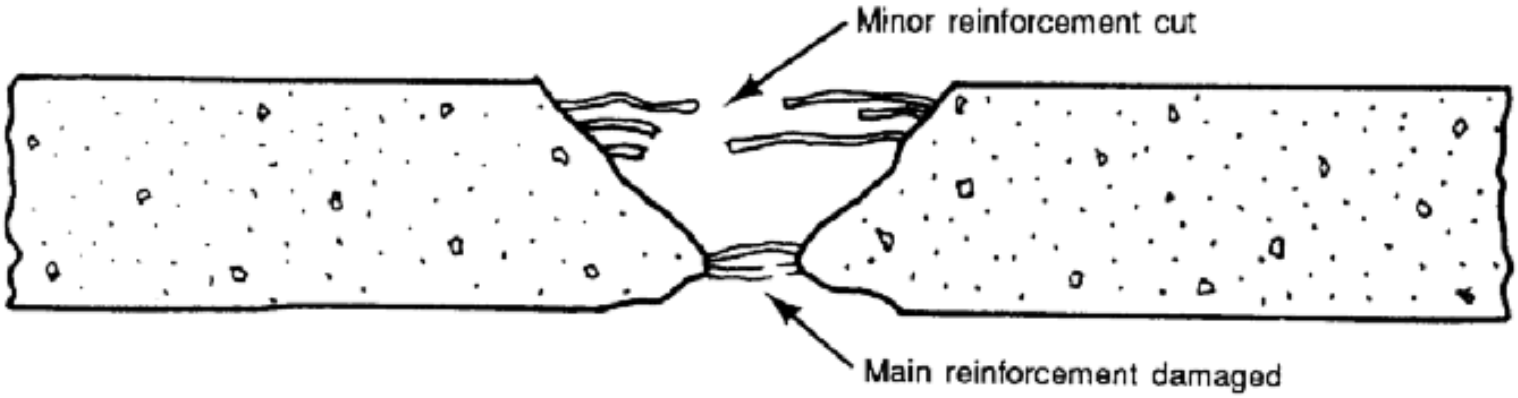


Figure 4-12. Effect of concrete charge

Although these charges cause some damage to the reinforcing steel, you will not be able to predict the extent of this damage. These charges are effective against reinforced-concrete beams and slabs up to 2 meters thick. Figure 4-12 shows the effect of the concrete-stripping charge. Using the proper charge size for the thickness of the target will— —

Remove all concrete from above the main reinforcing steel.

Remove all concrete from below the main reinforcing steel (spalling).

Damage the main reinforcing steel to some extent.

Destroy the minor reinforcing steel near the surface under the charge.

b. Charge Calculations (Simply Supported Bridges). For all simply supported concrete bridges, removing all concrete over a specified LC will cause collapse. For beam-and-

slab bridge spans (T-beam and I-beam bridges), determine the charge sizes for the beams and slab separately.

Example A-12 (page A-10) shows how to calculate beam-and-slab bridge charges. Use the following procedure for determining charge sizes for simply supported spans:

(1) Calculate the mass of the charge required:

$$P = 3.3(3.3\ h + 0.5)^3$$ where—

P = required charge size, in pounds per meter of bridge width.

h = beam or slab plus roadway depth, in meters (minimum is 0.3 meters and maximum is 2 meters).

(2) Calculate the width of the required ditch. The charge will produce a ditch across the width of the bridge. To determine the width of this ditch, use the following formula:

Wd = 2 h + 0.3 (4-2)

where-Wd = ditch width, in meters.

h = overall roadway and beam or slab depth, in meters.

(3) Compare the required Wd with the required LC, and take the appropriate action:

If LC is equal to or less than Wd, use one row of charges

as specified by P.

If LC is greater than Wd, but less than twice Wd, increase the size of charge by 10 percent.

If LC is twice Wd, double the charge and place them in two lines, side by side.

(4) Place charges in a continuous line across the full width of the bridge at the point of attack.

The shape of the end cross section of the charge should be such that the width is between one and three times the height.

(5) Tamp the charges, if required. No tamping is required for the concrete stripping charge as calculated, but if tamping with two filled sandbags per pound of explosive is used, reduce the calculated mass of charge by one third. The width of ditch formed will remain the same as for the original mass of charge.

Section III. Bridge Attacks

4-10. Guidelines (Continuous and Simply Supported Bridges). There are a number of factors that will assist you inadequately differentiating simply supported bridges from continuous bridges.

Figure 4-13 and the subparagraphs below describe these factors.

a. Continuity. In simply supported bridges, the entire superstructure is composed of a span or multiple spans supported at each end. The main structural members (individual spans) meet end to end, and each intermediate pair of ends is supported by a pier. The single ends are supported by the abutments. In continuous bridges, the main structural members are formed into one piece and do not have breaks over the piers, if any are present.

b. Construction Depth. In multispan, simply supported bridges, the construction depth of the span may decrease at the piers. In continuous bridges, construction depth frequently increases at the piers.

c. Flange Thickness (Steel-Girder Bridges). In simply supported, steel-girder bridges, the thickness of the flange frequently increases at midspan. In continuous bridges, the size of the flange frequently increases over the piers.

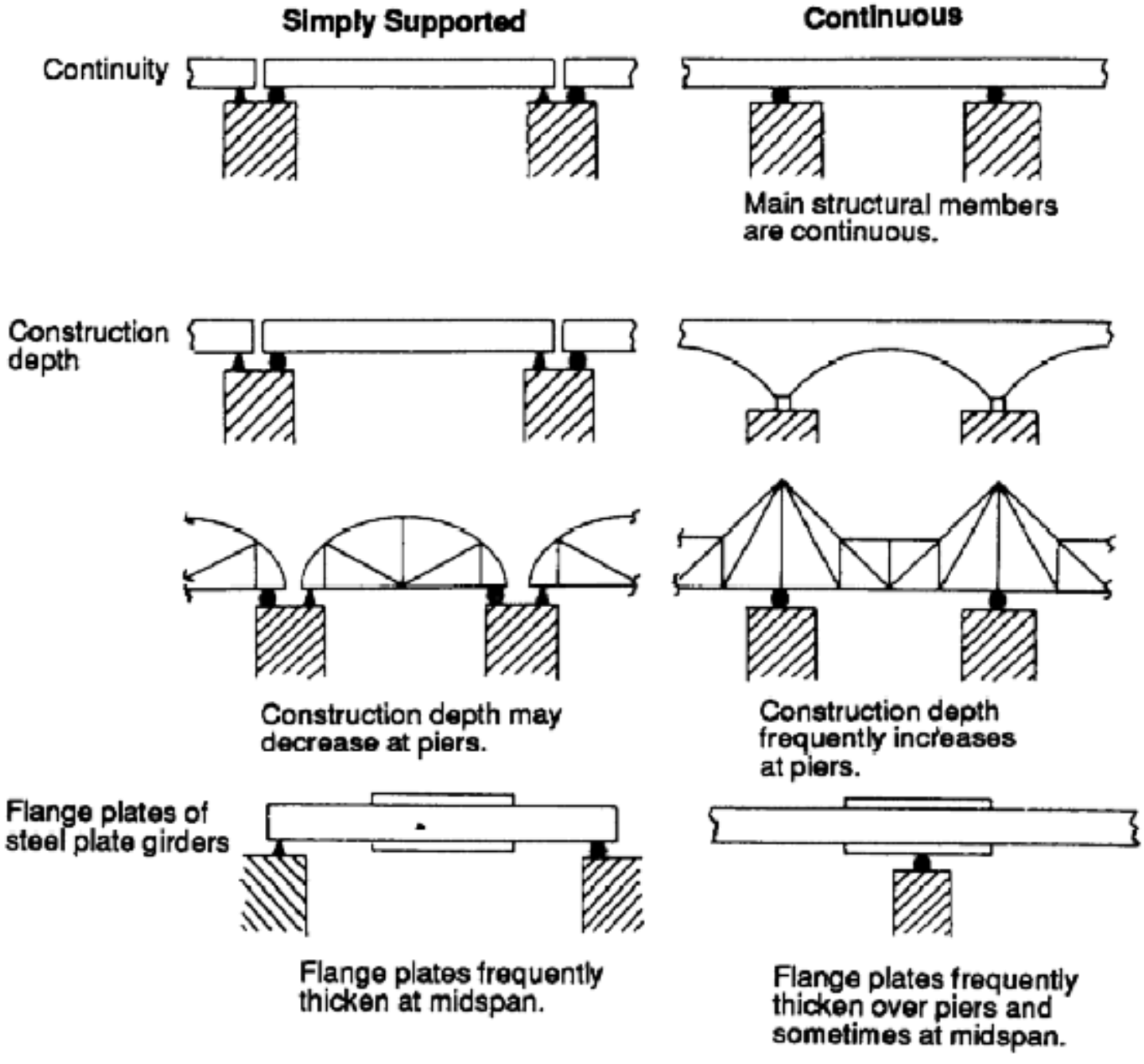
d. Bearing. Multispan, simply supported bridges require two lines of bearing at the piers; continuous bridges require only one.

e. Category Selection.

The external appearance of a bridge can sometimes be deceptive.Whenever possible, consultconstruction drawings to ascertain the correct bridge category. If drawings are not available and there is any uncertainty about the category to which the bridge belongs, assume the bridge is of continuous construction. Since more

explosive is necessary to demolish a continuous bridge, assuming a continuous construction will provide more than enough explosive to demolish a bridge of unknown construction.

f. Reconnaissance Procedures. To correctly use the tables in Appendix H, decide whether the bridge is in the simply supported, continuous, or miscellaneous category, and follow the procedures outlined in the appropriate paragraph.


Simply Supported
Continuous
Continuity
Main structural members are continuous.
Construction depth
Construction depth may decrease at piers.
Construction depth frequently increases at piers.
Flange plates of steel plate girders
Flange plates frequently thicken at midspan.
Flange plates frequently thicken over piers and sometimes at midspan.
Bearings

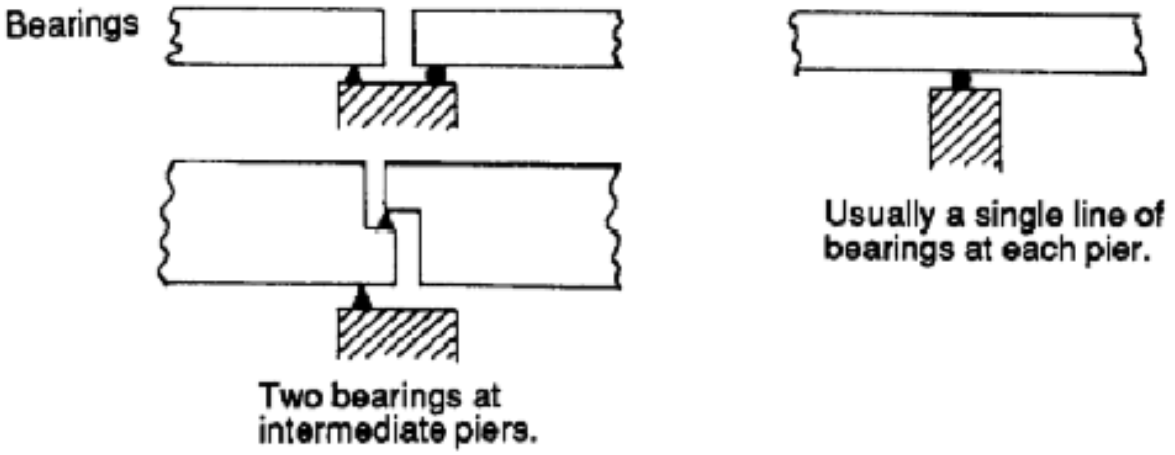


Figure 4-13. Span differences

4-11. Simply Supported Bridges.

a. Categorization. There are four main subcategories: steel beam, steel truss, concrete beam and slab, and bowstring.

The first three are further subdivided into deck bridges, which carry their loads on top of the main structural members. When dealing with deck bridges, note the locations of bearing (supporting the top or bottom chord or flange), as this will influence the possibility of jamming.

(1) Steel-Beam Bridges. Stell-beam bridges may be constructed of normal steel-beam, plate-girder, or box-girder spans. Figure 4-15 shows typical cross sections of these spans.

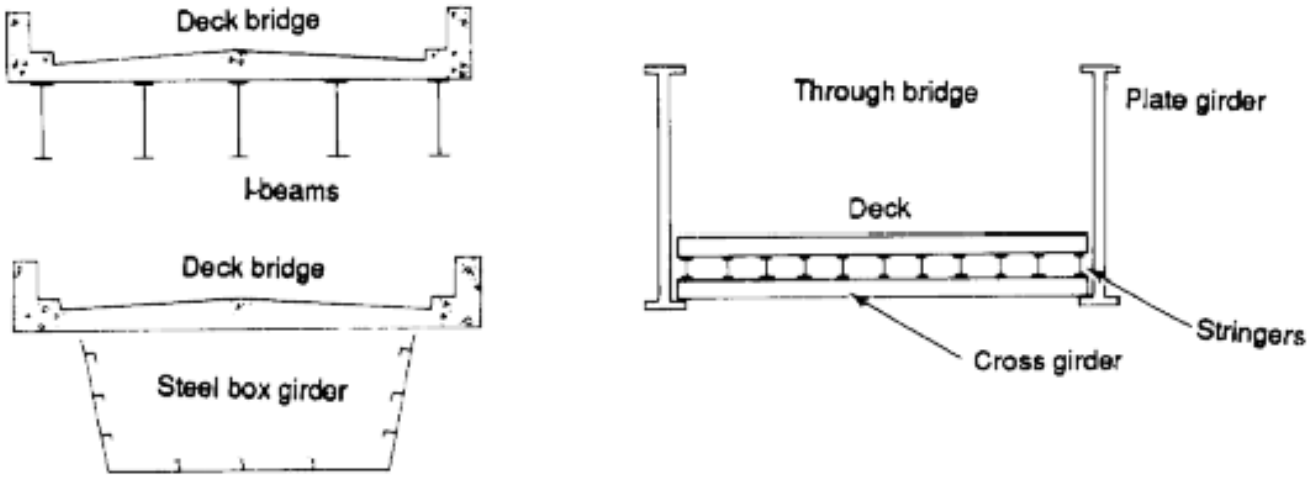
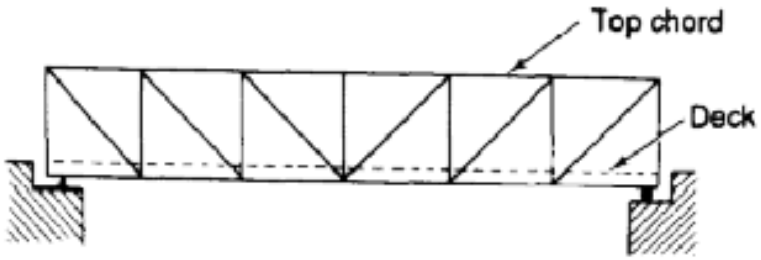


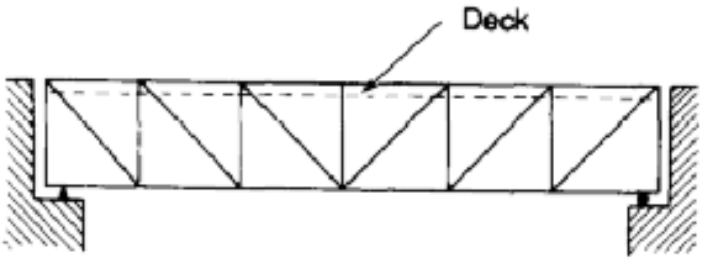
Figure 4-15. Typical cross sections of steel-beam bridges

(2) Steel-Truss Bridges. Figure 4-16 shows the side elevations for three normal steel-truss spans. Note that all truss bridges have diagonal members in the trusses.

Simply supported, steel-truss through bridge



Simply supported, steel-truss deck bridge (bottom support)



Simply supported, steel-truss deck bridge (top support)

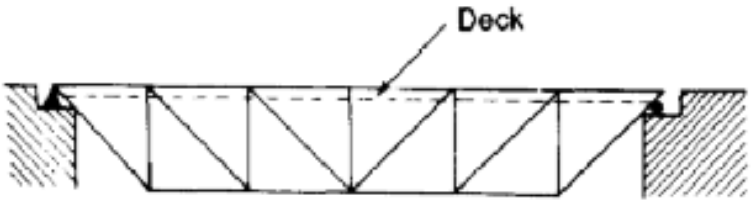


Figure 4-16. Side elevation of steel-truss bridges

(3) Concrete-Beam-and-Slab

Bridges. For categorization purposes, you will not need to distinguish between reinforced- and

prestressed-concrete bridges, as the methods of attack are the same for both. Figure 4-17 shows midspan cross-sectional views of these types of bridges. At midspan, the majority of steel reinforcing rods or tendons are located in the bottom portion of the superstructure. The attack methods detailed in Appendix H take this reinforcing condition into account.

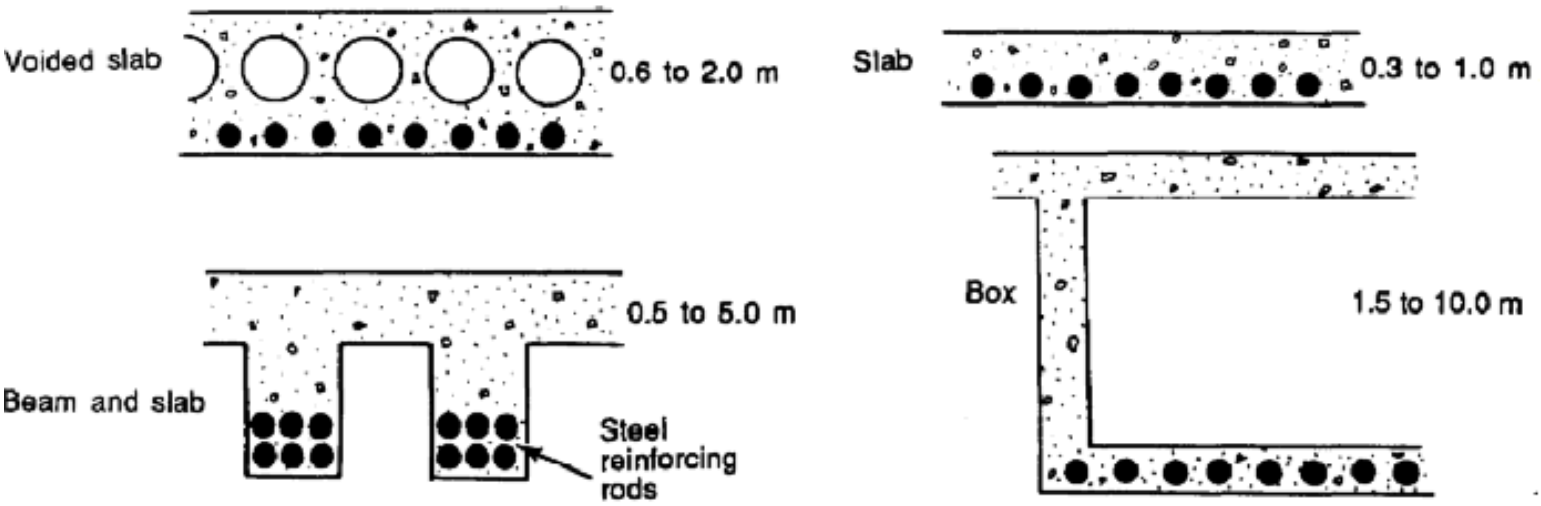


Figure 4-17. Midspan, cross-sectional views of typical concrete bridges

(4) Bowstring Bridges. Note the following about bowstring bridges:

(a) Features. Figure 4-18 (page 4-12) shows the features of a normal bowstring bridge. Recognize that—

The bow is in compression.

The bow may be a steel beam, box girder, concrete beam,

or steel truss.

The bow's depth (thickness) is larger than or equal to the depth of the deck support members.

The deck acts as a tie and resists the outward force applied by the bow.

The deck is designed as a weak beam supported by the hangers.

There is no diagonal bracing between the hangers.

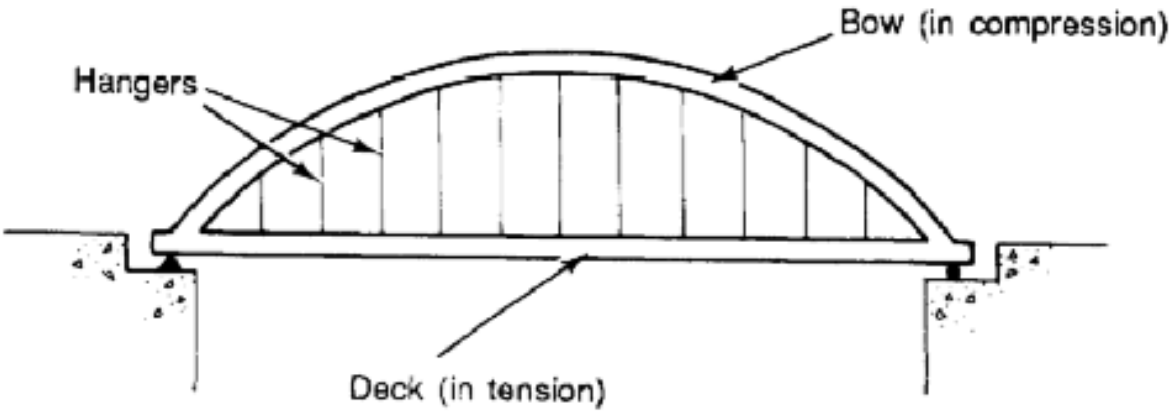


Figure 4-18. Normal bowstring bridge

(b) Uses. Occasionally the bow and hangers are used to reinforce a steel-beam or-truss bridge.

Categorize this type of bridge as a bowstring reinforced-beam or -truss bridge. In this type of bridge, the depth (thickness) of the bow will always be less than the depth of the deck support members.

(c) Pseudo-bowstring bridges. The bridge illustrated in

Figure 4-20 is not a bowstring, but an arch bridge. Categorize this type of bridge as an arch bridge because the outward forces of-the arch (pseudo bow) are restrained primarily by the abutments, not the deck.

b. Reconnaissance. For simply supported bridges, use the following reconnaissance procedure:

(1) Categorize the bridge.

(2) Measure the bridge

(Figure 4-21):

(a) Length (L). Measure the length of the span to be attacked, in meters.

NOTE: This distance is not the clear gap, but the length of the longitudinal members that support the deck from end to end.

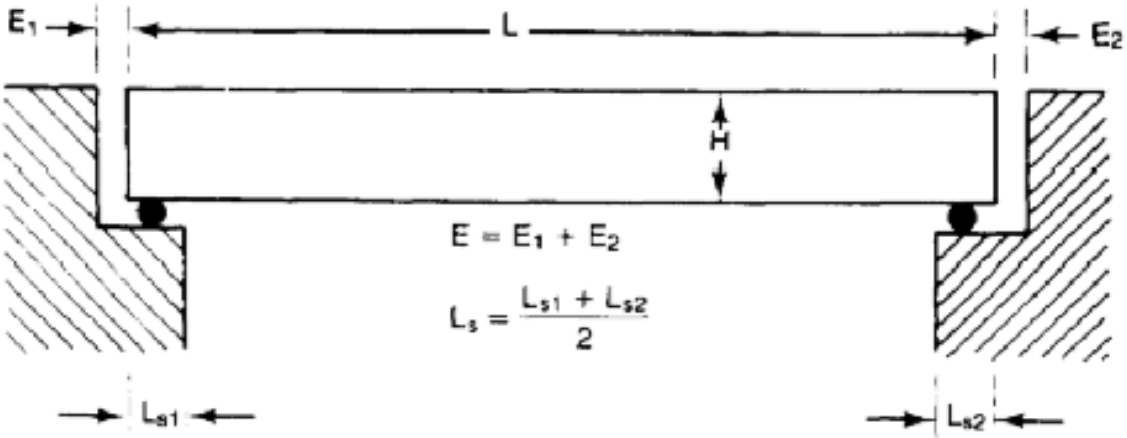


Figure 4-21. Measurements of simply supported spans

(b) Depth (H). Measure the depth of the beam, truss, or bow, in meters (include the deck with the beam or truss measurement).

(c) Total end clearance (E). Total the amount of end clearance at both ends of the span, in meters.

(d) Average length of the bearing supports (LS). Measure the average length of the bearing supports from the ends of the spans to the faces of the abutments or piers, in meters.

(3) Determine the attack method.

(4) Determine the critical dimensions of the span required for charge calculations.

c. Attack. Two considerations apply when attacking a simply supported span:

(1) Point of Attack. Attack simply supported bridges at or near midspan, because—

Bending moments are maximum at midspan.

The likelihood of jamming during collapse is reduced if the bridge is attacked at midspan.

(2) Line of Attack. Make the line of attack parallel to the lines of the abutments (Figure 4-22). Doing this reduces the risk that the two parts of the span will slew in opposite directions and jam. Do not employ any technique that induces twist in the bridge. If the line of attack involves cutting across transverse beams, reposition the line of attack to cut between the transverse beams.

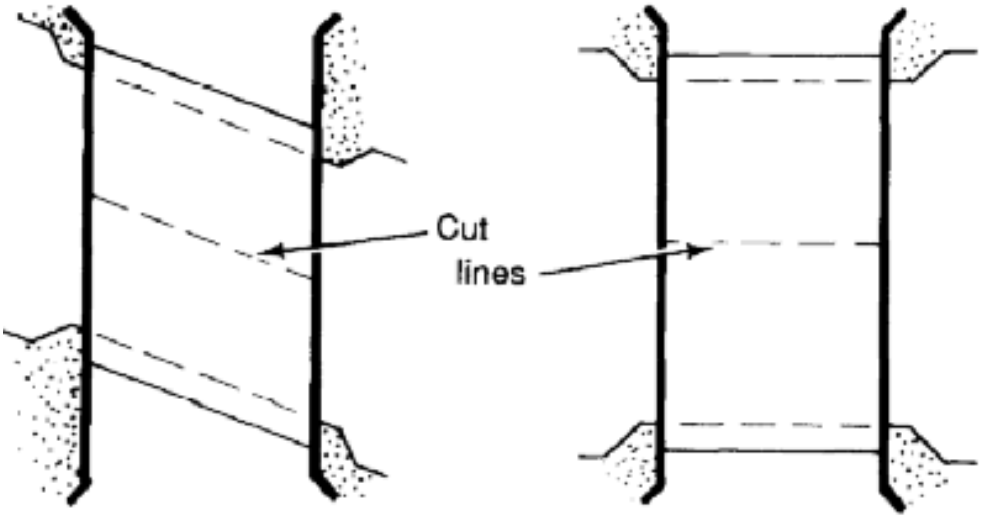


Figure 4-22. Line of attack

d. Attack Methods. Table H-3 (page H-3) lists in recommended order, attack methods likely to produce the most economical demolition, by bridge category. Within each category are variations to accommodate differences in construction materials, span configurations, load capacities (road, rail, or both), and gap and abutment conditions. The three recommended ways of attacking simply supported spans are bottom, top, and angled attacks. In all cases, ensure jamming cannot occur during collapse.

(1) Bottom Attack. Use the bottom attack whenever possible, as it leaves the roadway open and enables you to use the bridge, even when the demolitions are at a ready-to-fire state (State 2).

Reinforced and prestressed (tension) beams are very vulnerable to bottom attack, as the steel cables and reinforcing bars run along the bottom portion of the beam and are thus covered by less concrete.

The major disadvantages of the bottom attack are the increased amount of time and effort necessary for placing and inspecting the charges. Because it is generally impracticable to place sufficient explosive below a reinforced or prestressed slab to guarantee a cut deeper than 0.15 meters, used the top or angled attacks listed in Table H-3 (page H-3) for these types of bridges. When Table H-3 (page H-3) lists a bottom attack, determine the required end clearance (ER) from Table H-1 (page H-1) to prevent jamming. If the total end clearance (E) is greater than ER, jamming will not occur.

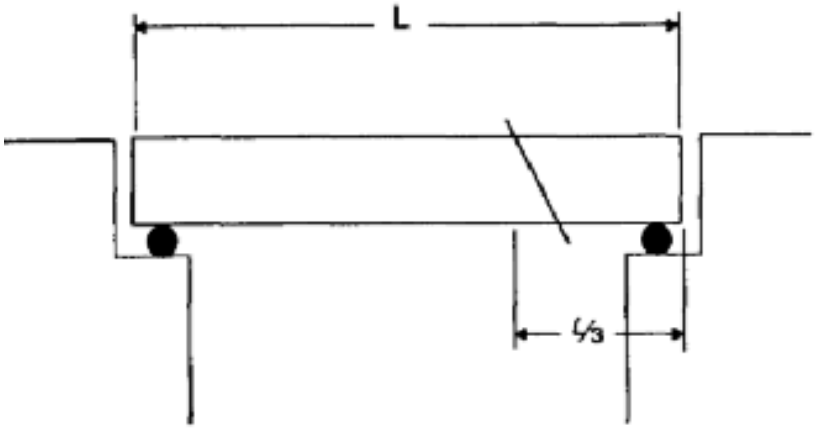
If E is less than ER, use a top or angled attack or destroy one abutment at the places where jamming would occur. Example A-13 (page A-12), explains the method for bottom attack calculations.

(2) Top Attack. When Table H-3 (page H-3) lists a top attack, LC must be removed from the top of the bridge to prevent jamming. Determine LC from Table H-2 (page H-2). Remove LC in a V-shaped section along the full depth of the target. For reinforced-concrete bridges, use a concrete-stripping charge (paragraph 4-9, page 4-7) to remove LC from the top of the bridge. This action, by itself, should cause collapse. There is no requirement to cut steel reinforcing rods.

Example A-14 (page A-13) shows the method for top attack calculations.

(3) Angled Attack. For angled attacks, cut all members (span, hand-rails, service pipes, and so forth) of the bridge. Make the angle of attack approximately 70 degrees to the horizontal to prevent jamming. The location of the charge should be between the midspan point and a point L/3 from the end (Figure 4-23).

Although an angled attack is effective on any type of bridge, it is essential when the bridge must be kept open to traffic, or when there is ample time to prepare demolitions.



Cut between L/3 span and midspan

Figure 4-23. Location of angled charge

4-12. Continuous Bridges.

a. Categorization. Figure 4-24 is a categorization chart for continuous bridges. Use this chart like the chart for simply supported bridges. There are six main subcategories: cantilever, cantilever and suspended span, beam or truss, portal, arch, and masonry arch. The first five categories differentiate between steel and concrete construction, as each material has a different attack method.

If a continuous bridge is of composite construction (for example, steel beams supporting a reinforced-concrete deck), the material that comprises the main, longitudinal load-bearing members will determine the attack method.

(1) Cantilever Bridges. A cantilever bridge has a midspan shear joint.

Note that the full lengths of the anchor spans may be built into the abutments, making the cantilever difficult to identify.

(2) Cantilever and Suspended-Span Bridges. If a cantilever bridge incorporates a suspended span (Figure 4-26, page 4-16) that is at least 5 meters longer than the enemy assault bridging capability, attack this section of the bridge; attacking this section requires less preparation. Because suspended spans are simply supported, use the attack method described for simply supported bridges (Table H-3, page H-3).

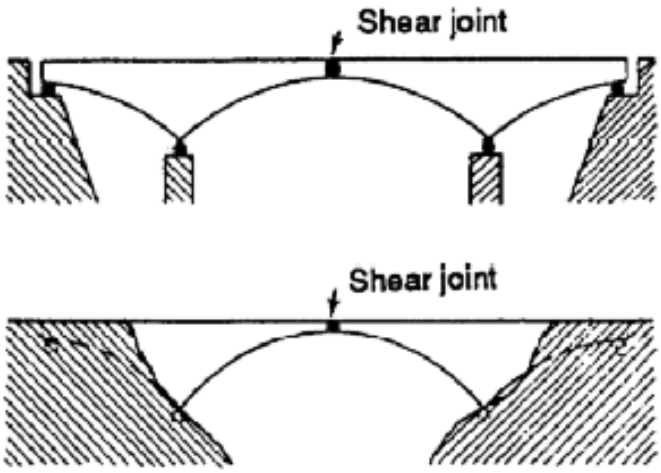


Figure 4-25. Cantilever bridges

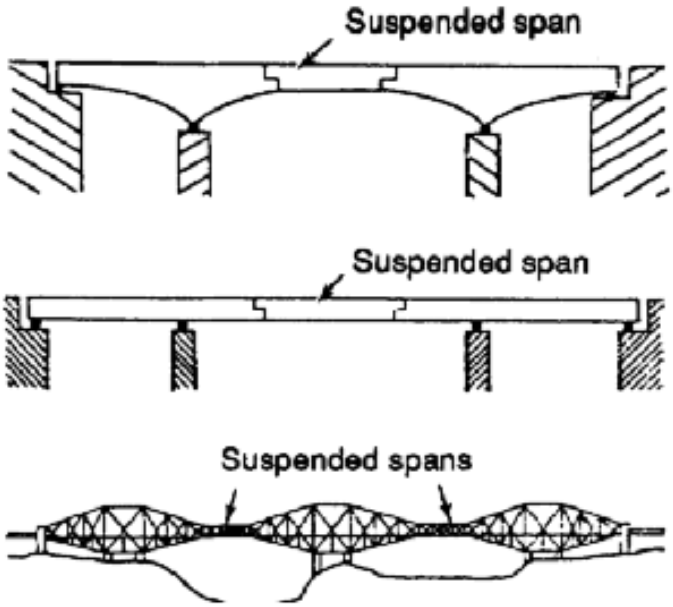


Figure 4-26. Cantilever and suspended span bridges

(3) Beam or Truss Bridges. For beam or truss bridges differentiate between those bridges with spans of similar lengths and those with short side spans because this affects the attack method. A short side span is one that is less than three quarters of the length of the next adjacent span.

(4) Portal Bridges. For portal bridges (Figure 4-30), differentiate between those with fixed footings and those with pinned footings, as this affects the attack method. If you cannot determine the type of footing, assume fixed footings. Portal bridges, as opposed to arch bridges, lack a smooth curve between the bearing point of the span and the span itself.

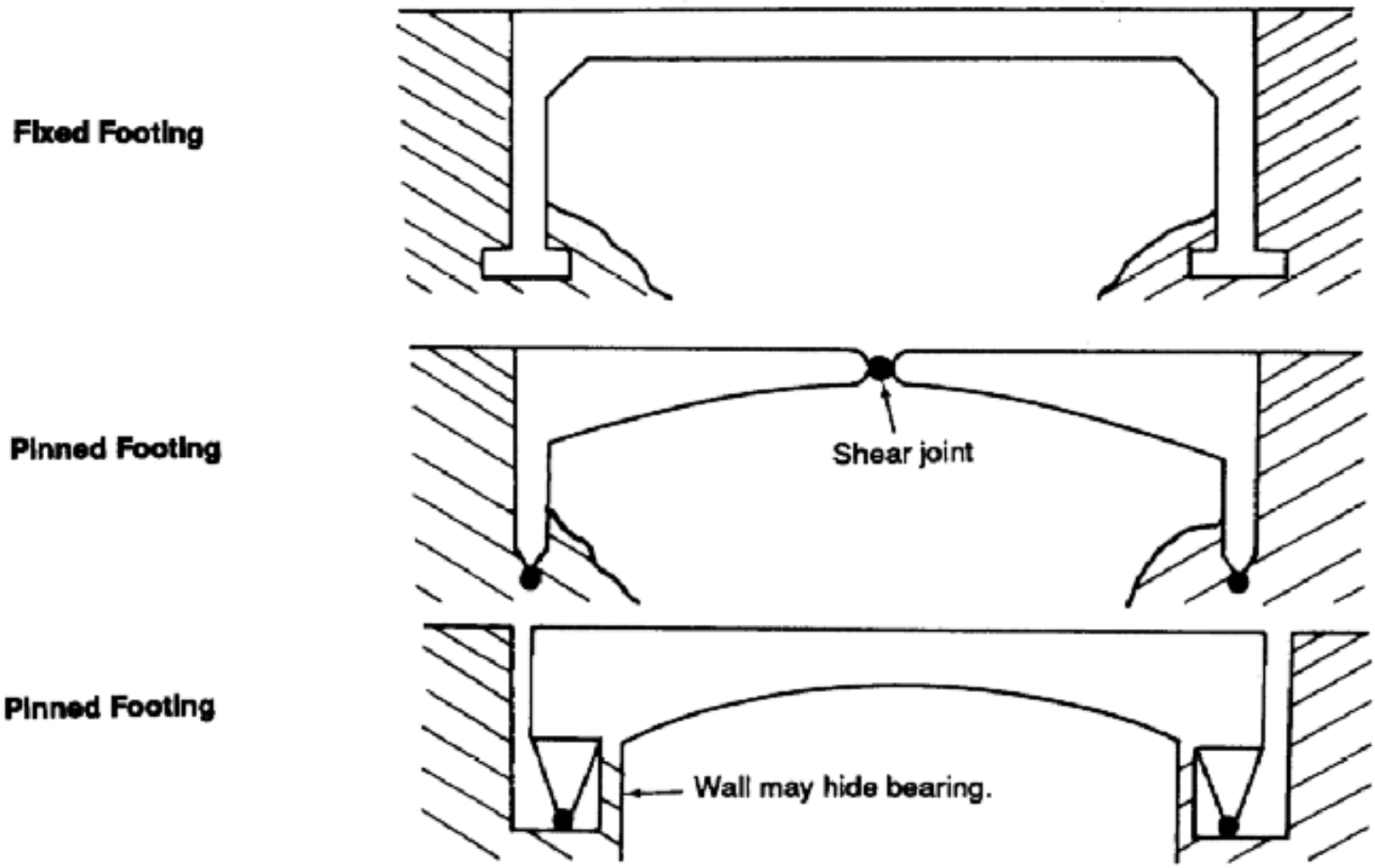


Figure 4-30. Typical portal bridges

(5) Arch Bridges. In arch bridges determine whether the bridge has an open or solid spandrel and fixed or pinned footings. Again, when in doubt, assume fixed footings.

(6) Masonry Arch Bridges. Identify masonry arch bridges by their segmental arch ring. However, it is easy to mistake a reinforced-concrete bridge for a masonry-arch bridge because many reinforced-concrete bridges have masonry faces. Always check the underside of the arch. The underside is rarely faced on reinforced-concrete bridges.

b. Reconnaissance. For continuous bridges, use the

following reconnaissance procedure:

(1) Categorize the bridge.

(2) Measure the bridge

(Figure 4-33):

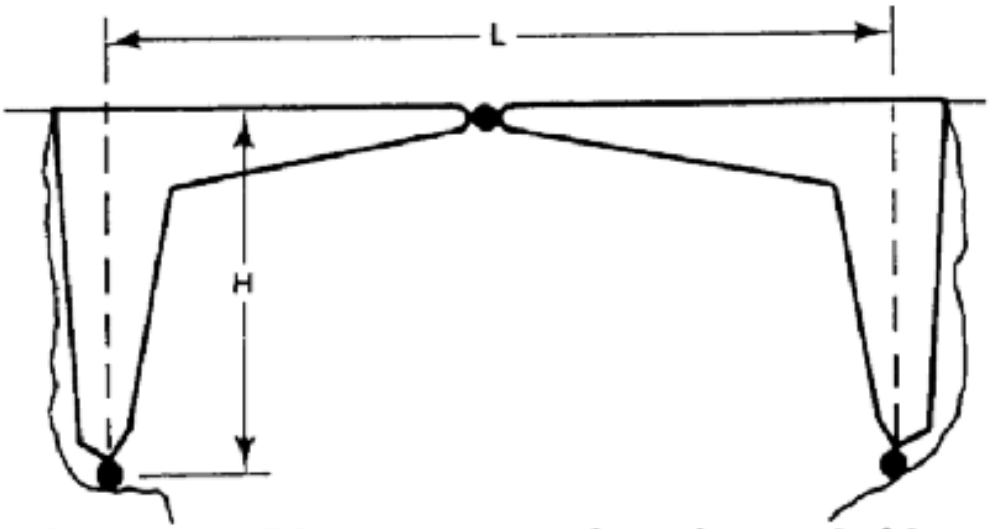


Figure 4-33. Measurements of continuous bridges

(a) Length (L).

Measure the span you plan to attack, in meters (between centerlines of the bearings).

(b) Rise (H). For arch and portal bridges, measure the rise, in meters (from the springing or bottom of the support leg to the deck or top of the arch, whichever is greater).

(c) Determine the attack method from Appendix H.

(d) Determine the critical dimensions necessary for charge calculations.

c. Bridge Attacks. As with simply supported spans, two

considerations apply when attacking continuous spans: the point of attack and line of attack. No common point-of-attack rule exists for all categories of continuous bridges, but the line-of-attack rule applies to all continuous bridges.

That is, the line of attack must be parallel to the lines of the abutments, and twisting must not occur during the demolition. If the recommended line of attack involves cutting across transverse beams, reposition the line to cut between adjacent transverse beams. Table H-4 (page H-7) lists attack methods for continuous spans.

(1) Steel Bridges. When attacking continuous-span steel bridges, use the see-saw or unsupported-member collapse mechanism. Both mechanisms produce complete cuts through the span. Providing you can properly place charges, you may be able to demolish these bridges with a single-stage attack. However, on particularly deep superstructures (concrete decks on steel beams), charges designed to sever the deck may not cut through all of the reinforcing steel. Therefore, during reconnaissance, always plan for the possibility of a two-stage attack on deep, composite superstructures. Make angle cuts at about 70 degrees to the horizontal to prevent jamming during collapse.

(2) Concrete Bridges. Continuous concrete bridges are the most difficult to demolish and hence are poor choices for reserved demolitions. Even when construction drawings are available and there is ample time for preparation,

single-stage attacks are rarely successful. Consider using a bottom attack for this bridge type.

(3) Arch and Portal Bridges. For arch bridges and portal bridges with pinned footings, collapse can be guaranteed only be removing a specified minimum span length. Determine this minimum length by using Table 4-1 and the L and H values determined by reconnaissance.

Table 4-1. Minimum L_C values for arch and pinned-footing bridge attacks

$\frac{H}{L}$	0.040	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200
$\frac{L_c}{L}$	0.003	0.007	0.013	0.020	0.030	0.040	0.053	0.067	0.083
$\frac{H}{L}$	0.220	0.240	0.260	0.280	0.300	0.320	0.340	0.360	
$\frac{L_c}{L}$	0.100	0.130	0.150	0.170	0.200	0.230	0.270	0.300	

NOTES:

1. The values in this table are based on the following formula:
$$\frac{L_c}{L} = 1 - [1 - 4(\frac{H}{L})^2]^{1/2}$$
2. If the result of $\frac{H}{L}$ is not on the chart exactly as calculated, round UP to the next higher value on the chart. For example, if $\frac{H}{L} = 0.089$, use the column headed 0.10 to determine $\frac{L_c}{L}$. In this case, $\frac{L_c}{L} = 0.02$. Multiply the $\frac{L_c}{L}$ value by L to get L_c. For example, $0.02 \times L = L_c$.

4-13. Miscellaneous Bridges.

a. Suspension-Span Bridges. Suspension-span bridges usually span very large gaps. These bridges have two distinguishing characteristics: roadways carried by flexible members (usually wire cable) and long spans.

(1) Components. The components of suspended-span

bridges are cables, towers, trusses or girders, and anchors. Suspension-bridge cables are usually multiwire-steel members that pass over the tower tops and terminate at anchors on each bank. The cables are the load-carrying members.

(The Golden Gate bridge has 127,000 miles of wire cable of this type.) The towers support the cables. Towers may be steel, concrete, masonry, or a combination of these materials. The trusses or girders do not support the load directly; they only provide stiffening. Anchors hold the ends of the cables in place and may be as large as 10,000 cubic feet.

(2) Demolishing Methods.

(a) Major bridges. Anchors for major suspension bridges are usually too massive to be demolished. The cables are usually too thick to be effectively cut with explosives. The most economical demolition method is to drop the approach span or a roadway section by cutting the suspenders of the main or load-bearing cables. The enemy’s repair and tactical bridging capabilities determine the length of the target section. When reinforced-concrete towers are present, it may be feasible to breach the concrete and cut the steel of the towers.

(b) Minor bridges. The two vulnerable points on minor suspension bridges are towers and cables. Use the following methods:

Towers. Destroy towers by placing tower charges slightly above the level of the roadway. Cut a section out of each side of each tower. Place the charges so that they force the ends of the cut sections to move in opposite directions, twisting the tower. Doing this will prevent the end of a single cut from remaining intact. Demolition chambers, provided in some of the newer bridges, make blasting easier, quicker, and more effective.

Cables. Destroy the cables by placing charges as close as possible to anchor points, such as the top of towers. Cables are difficult to cut because of the air space between the individual wires in the cable. Ensure the charge extends no more than one half the cable's circumference. These charges are usually bulky, exposed, and difficult to place. Shaped charges are very effective for cable cutting.

b. Movable Bridges. These bridges have one or more spans that open to provide increased clearance for waterway traffic. The three basic types of movable bridges are swing-span, bascule, and vertical-lift. The characteristics of these bridges are described in the next paragraphs.

(1) Swing-Span Bridges.

(a) Characteristics. A swing span is a continuous span capable of rotating on a central pier. The arms of a swing-

span bridge may not be of equal length. If the arms are not of equal length, weights are added to balance them. Rollers that run on a circular track on top of the central pier carry the span's weight. The swing span is independent from any other span in the bridge. Identify a swing-span bridge by its wide, central pier. This central pier is much wider than the one under a continuous-span bridge that accommodates the rollers and turning mechanism (Figure 4-35).

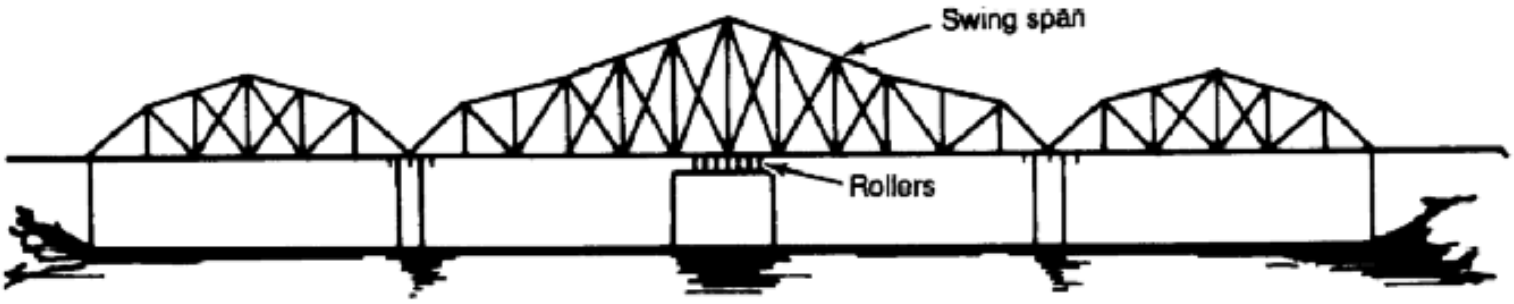


Figure 4-35. Swing-span truss bridge

(b) Demolition methods. Because swing-span bridges are continuous bridges, use an attack method from the continuous bridge section in Appendix H. For partial demolition, open the swing span and damage the turning mechanism.

(2) Bascule Bridges.

(a) Characteristics. Bascule bridges are more commonly known as drawbridges. These bridges usually have two leaves that fold upward (Figure 4-36), but some bascule bridges may have only one leaf (Figure 4-37). The movable leaves in bascule bridges appear in three general forms: counterweights below the road level (most modem),

counterweights above the road level (older type), and no counterweights (lifted by cable or rope; oldest type; usually timber).

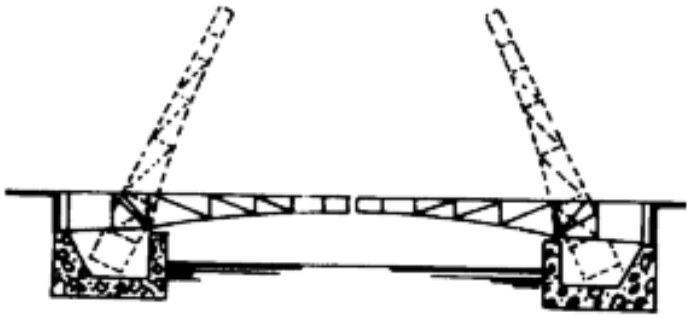


Figure 4-36. Double-leaf bascule bridge

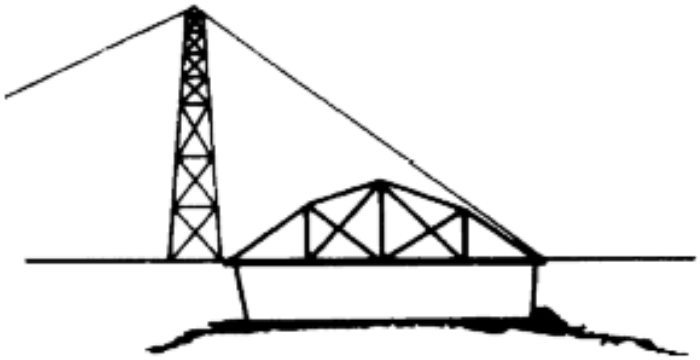


Figure 4-37. Single-leaf bascule bridge

(b) Demolition methods. Demolish the cantilever arms with an attack method appropriate for simply supported bridges. For partial demolition, open the bridge and jam or destroy the lifting mechanism.

(3) Vertical-Lift Bridges.

(a) Characteristics. These bridges have simply supported, movable spans that can be raised vertically in a horizontal position. The span is supported on cables that pass over rollers and connect to large, movable counterweights.

(b) Demolition methods. Demolish the movable span with an attack method appropriate for simply supported bridges. Another method is to raise the bridge and cut the lift cables on one end of the movable span. The movable span will either wedge between the supporting towers or fall free and severely damage the other tower.

(4) Floating Bridges. Floating bridges consist of a

continuous metal or wood roadway supported by floats or pontoons

(a) Pneumatic floats. Pneumatic floats are airtight compartments of rubberized fabric inflated with air. For hasty attack of these bridges, cut the anchor cables and bridle lines with axes and the steel cables with explosives. Also, puncture the floats with small-arms or machine-gun fire. Using weapons to destroy the floats requires a considerable volume of fire because each float has a large number of watertight compartments. Another method is to make a clean cut through the float, using detonating cord stretched snugly across the surface of the pontoon compartments.

One strand of cord is enough to cut most fabrics, but two strands may be necessary for heavier materials. Also, place one turn of a branch-line cord around each inflation valve. This will prevent the raft from being reinflated if it is repaired. Do not use main-line cords to cut valves because the blast wave may fail to continue past any sharp turn in the cord.

b) Rigid pontoons. Rigid pontoons are made of various materials: wood, plastic, or metal. To destroy these bridges, place a ½-pound charge on the upstream end of each pontoon at water level.

Detonate all charges simultaneously. If the current is rapid, cut the anchor cables so that the bridge will be

carried downstream. Another method is to cut the bridge into rafts. Place ½-pound charges at each end of each pontoon and detonate them simultaneously. To destroy metal treadways on floating bridges, use the steel-cutting formula (paragraph 3-6, page 3-8). The placement and size of the charges depend on bridge type. Typically, placing cutting charges at every other joint in the treadway will damage the bridge beyond use.

(5) Bailey Bridges. To destroy these bridges, place l-pound charges between the channels of the upper and lower chords. Use ½-pound charges for cutting diagonals and l-pound charges for cutting sway bracing (Figure 4-40).

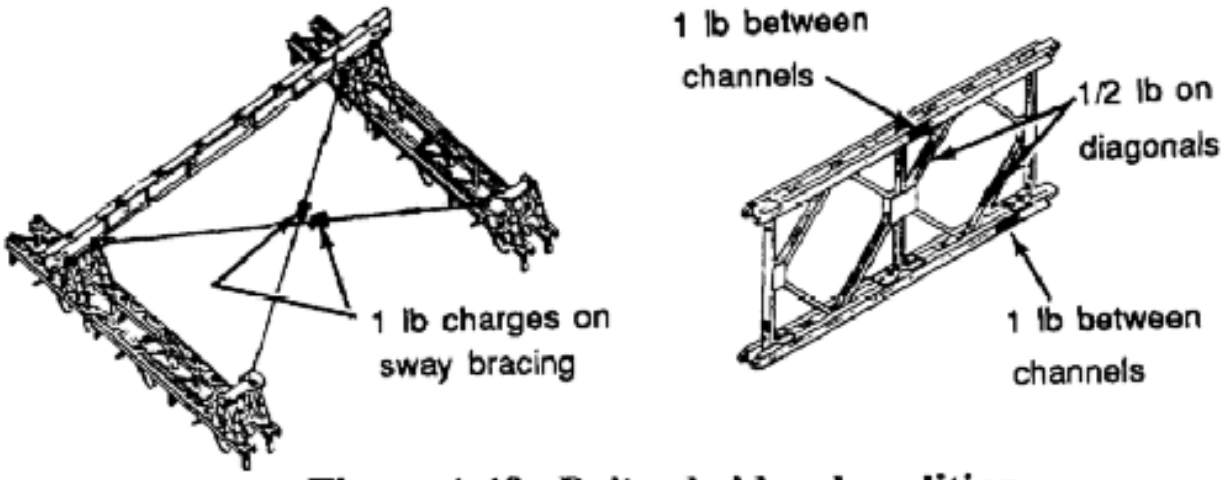


Figure 4-40. Bailey bridge demolition

(a) In-place demolitions. Cut the bridge in several sections by attacking the panels on each side, including the sway bracing. The angle of attack should be 10 degrees to the horizontal to prevent jamming. In double-story or triple-story bridges, increase the charges on the chords at the story-junction line. For further destruction, place charges on the transoms and stringers.

(b) In-storage or-stockpile demolition. When abandoning bridges in storage, do not leave any component the enemy can use as a unit or for improvised construction. Do this by destroying the essential components that the enemy cannot easily replace or manufacture. Panel sections fulfill the role of essential components. To render the panel useless, remove or distort the female lug in the lower tension chord. Destroy all panels before destroying other components.

Section III. Abutments and Intermediate Supports

4-14. Abutments. To demolish abutments, place charges in the fill behind the abutment. This method uses less explosive than external breaching charges and also conceals the charges from the enemy. The disadvantage is the difficulty in placing the charges. When speed is required, do not place charges behind abutments if you know the fill contains large rocks.

a. Abutments (5 Feet Thick or Less). Demolish these abutments by placing a line of 40-pound cratering charges, on 5-foot centers, in boreholes 5 feet deep, located 5 feet behind the face of the abutment (triple-nickel-forty method). Place the first hole 5 feet from either end of the abutment and continue this spacing until a distance of 5 feet or less remains between the last borehole and the other end of the abutment (Figure 4-41). If the bridge approach is steep, place the breaching

charges against the rear of the abutment. Determine the number of 40-pound cratering charges as follows:

$$N = \frac{W}{5} - 1$$

where—

N = number of charges; round UP to next higher whole number.

W = abutment width, in feet.

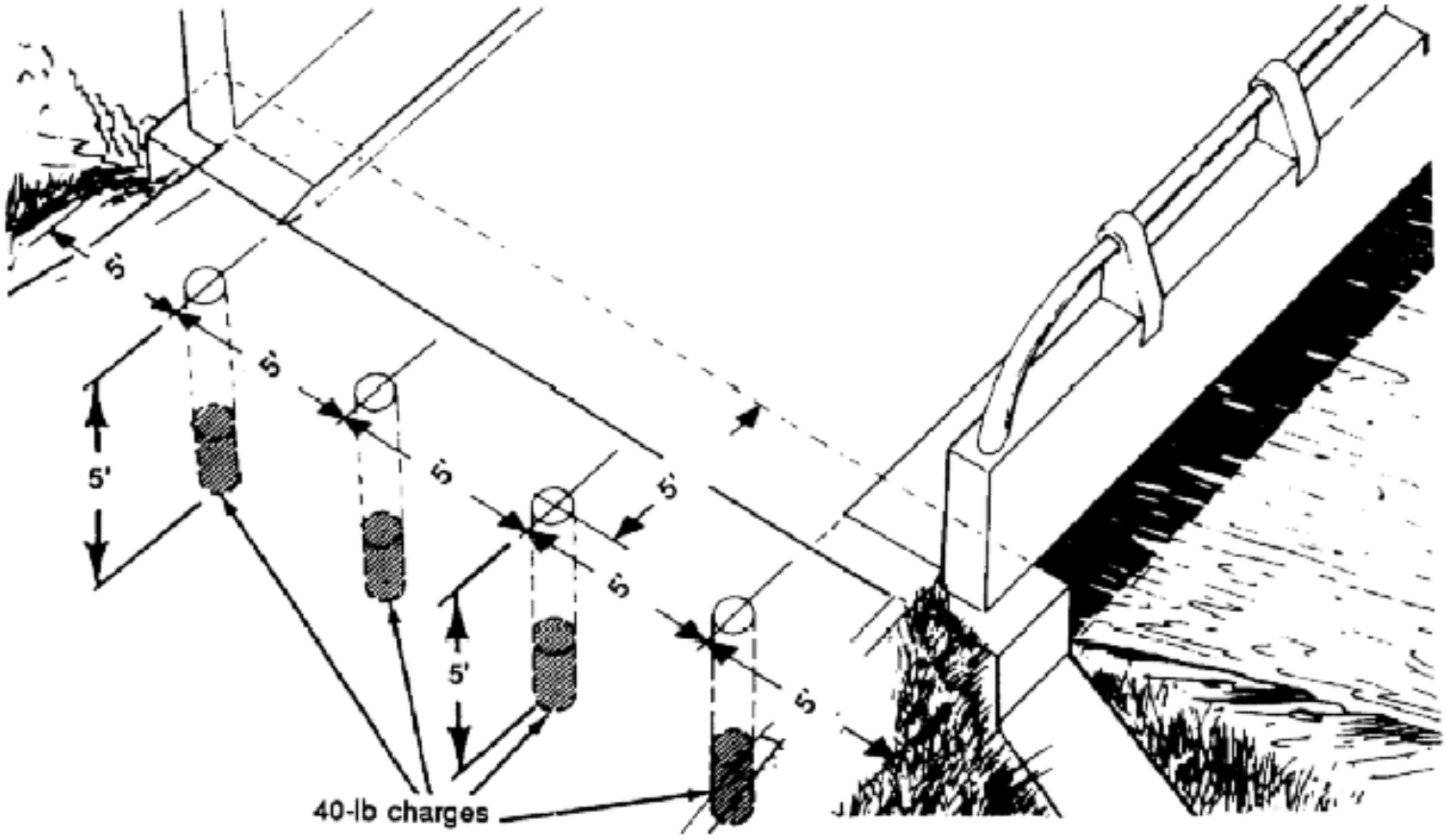
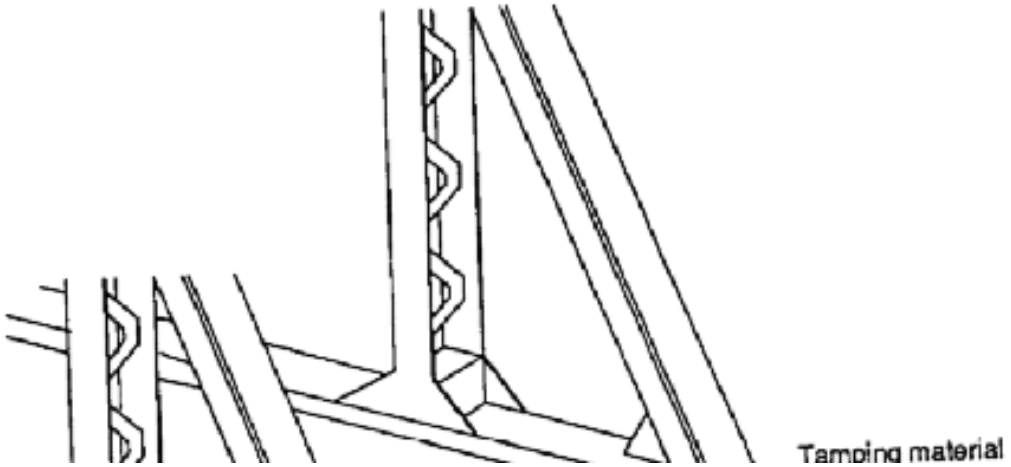


Figure 4-41. Abutment destruction (5 feet thick or less)



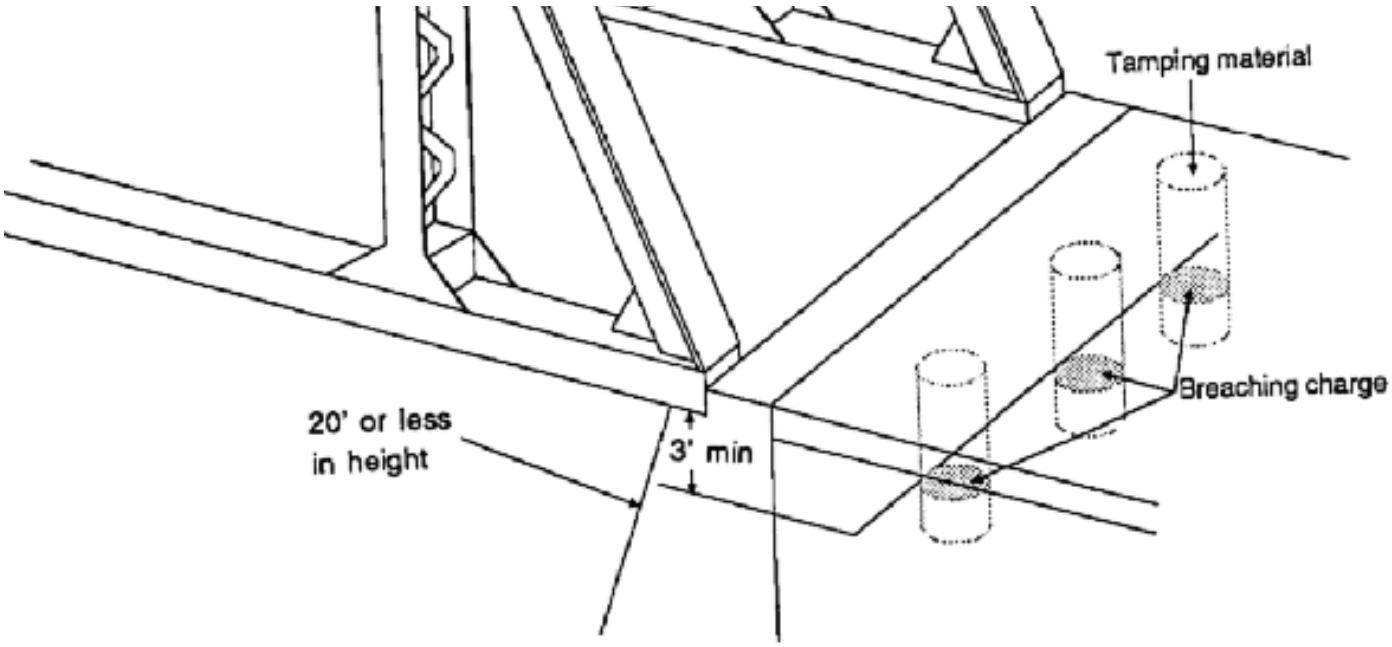


Figure 4-42. Abutment destruction (over 5 feet thick)

b. Abutments (0ver 5 Feet Thick). Destroy these abutments with breaching charges in contact with the back of the abutment. Calculate the amount of each charge using the breaching formula in equation 3-6 (page 3-16). Use the abutment thickness as the breaching radius. Determine the number of charges and their spacing using equation 3-7 (page 3-19). Place charges at least three feet below the bridge seat (where the bridge superstructure sits on the abutment) (Figure 4-42).

c. Abutments (Over 20 Feet High). Demolish these abutments by placing a row of breaching charges at the base of the abutment on the gap side, in addition to the charges specified in paragraphs 4-14a or 4-14b above. Fire all charges simultaneously. This method tends to overturn and completely destroy the abutment.

d. Wing Walls. If the wing walls can support a rebuilt or temporary bridge, destroy the wing walls by placing

charges behind them in the same manner as for abutments (Figures 4-41 and 4-42).

4-15. Intermediate Supports. Demolish concrete and masonry piers with internal or external charges (Figure 4-43).

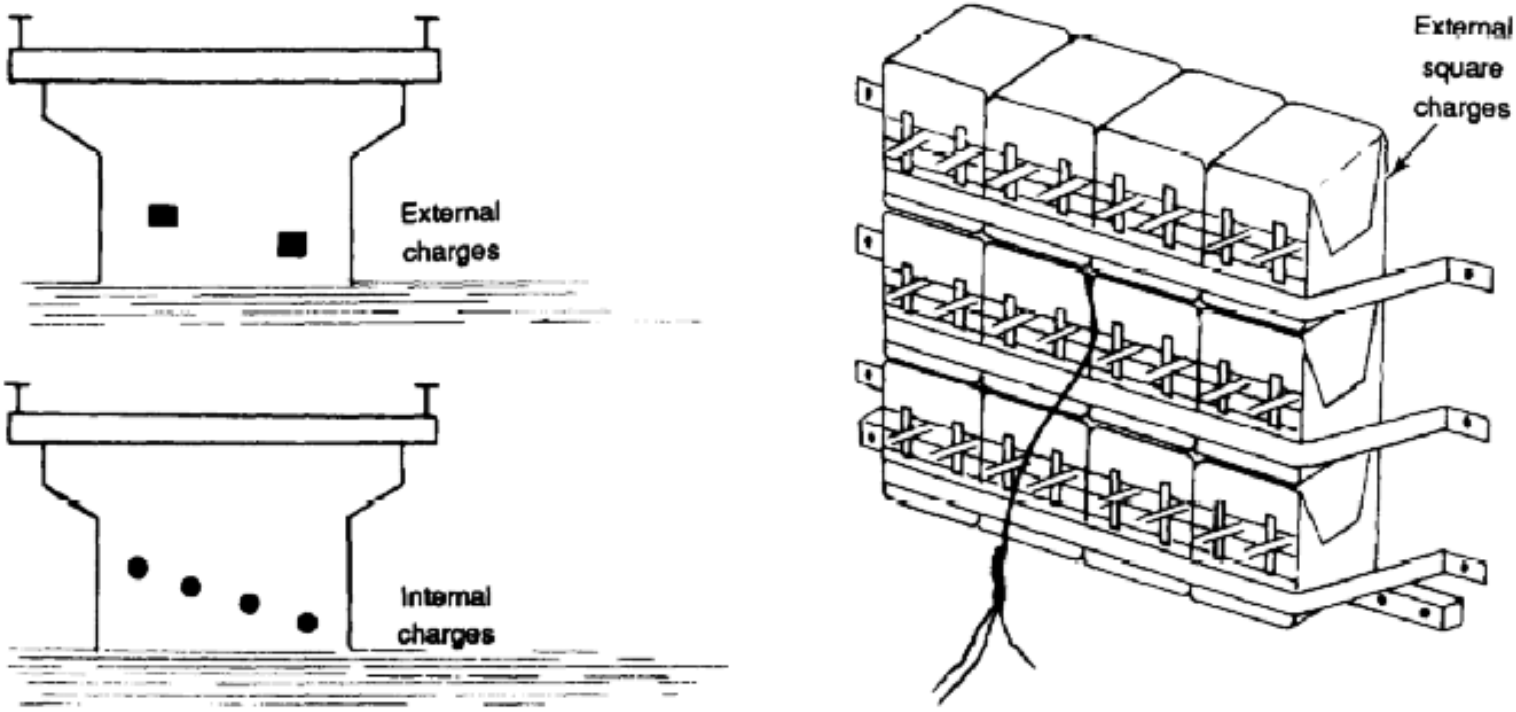


Figure 4-43. Placing charges on intermediate supports

a. Internal Charges. These charges require less explosive than do external charges. However, unless the support has built-in demolition chambers, this method requires an excessive amount of equipment and preparation time. Use equation 3-6 (page 3-16) to determine the amount of each charge. MI12 (C4) is ideal for internal charges. Thoroughly tamp all charges of this type with nonsparking tools (blunt, wooden tamping sticks or similar tools). If the support has demolition chambers, place the charges in boreholes created with shaped charges or drilled with pneumatic or hand tools. A 2-inch-diameter borehole holds

approximately 2 pounds of explosive per foot of depth. The steel reinforcing bars, however, make drilling in heavily reinforced concrete impractical.

b. External Charges. Place these charges at the base of the pier or higher, and do not space the charges by more than twice the breaching radius. Stagger the charges to leave a jagged surface to hinder future use. Thoroughly tamp all external charges with earth and sandbags, if time, size, shape, and location of the target permit.

NEXT

BACK TO COMMERCIAL EXPLOSIVES

Chapter 6

Demolition Safety

Section I. General Safety

6-1. Considerations.

Do not attempt to conduct a demolitions mission if you are unsure of demolition procedures; review references or obtain assistance.

Prevent inexperienced personnel from handling explosives.

Avoid dividing responsibility for demolition operations.

Use the minimum number of personnel necessary to accomplish the demolitions mission.

Take your time when working with explosives; make your actions deliberate.

Always post guards to prevent access inside the danger radius.

Always maintain control of the blasting machine or initiation source.

Use the minimum amount of explosives necessary to accomplish the mission while keeping sufficient

explosives in reserve to handle any possible misfires.

Maintain accurate accountability of all explosives and accessories. Always store blasting caps separately and at a safe distance from other explosives.

Ensure all personnel and equipment are accounted for prior to detonating a charge.

Ensure you give warnings before initiating demolitions; give the warning "Free in the hole!" three times.

Always guard firing points.

Assign a competent safety officer for every demolition mission.

Dual initiate all demolitions, regardless of whether they are single-or dual-primed.

Avoid using deteriorated or damaged explosives.

Do not dismantle or alter the contents of any explosive material.

Avoid mixing live and inert (dummy) explosives.

WARNING

Do not use blasting caps underground.

Use detonating cord to prime underground charges.

6-2. Explosive Materials.

a. Blasting Caps. Both military and commercial blasting caps are extremely sensitive and can explode unless handled carefully. Blasting caps can detonate if exposed to extreme heat (cook off).

Military blasting caps are more powerful and often more sensitive than their commercial counterparts. When using commercial blasting caps to detonate military explosives, ensure they are powerful enough to detonate the explosives, thus, avoiding misfires. Because power requirements for caps from different manufacturers vary, never mix caps from different manufacturers; mixing caps could result in rnisfires. When installing caps in explosives, never force them into an explosive or a cap well; use an appropriate tool for making or enlarging the cap well.

Ensure 1/8 to 1/4 inch of the cap is clearly visible at both ends when taping onto detonation cord. Do not connect blasting-cap initiation sets to ring or line mains or charges when nonessential personnel are on site. Never leave blasting caps unattended before or after attaching them to the charges or firing system.

(1) Nonelectric.

Use only authorized equipment and procedures when crimping nonelectric blasting caps to time fuse or detonating cord.

Maintain blasting caps in the appropriate cap box until needed. Never store blasting caps with explosives.

Never carry loose blasting caps in your pocket or place loose blasting caps in a container; secure them.

Do not blow into a nonelectric cap or attempt to remove any obstructions from the blasting cap well. Remove obstructions that will dislodge by using the wrist-to-wrist tap method.

Never insert anything but time fuse or detonation cord into a nonelectric blasting cap.

Do not twist time fuse or detonating cord while attempting to insert into a blasting cap.

Never attempt to crimp a blasting cap installed in an explosive. If the blasting cap has come loose from the time fuse or detonating cord, remove the blasting cap from the charge, recrimp the cap, and then reinstall the cap in the charge.

Avoid striking, pinching, and mashing nonelectric caps during crimping activities. Use only the M2 crimpers for

all crimping operations.

When using nonelectric caps to dual prime demolitions, cut the fuse to allow an interval of not less than 10 seconds between firings.

(2) Electric.

Do not remove the short-circuiting shunt unless testing or connecting the cap. The shunt prevents accidental initiation by static electricity. If the blasting cap has no shunt, twist the bare ends of the lead wires together at least three times (180-degree turns) to provide a proper shunt.

Use proper grounding procedures when static electricity is present, see paragraph 6-5b (page 6-4).

When transporting electric blasting caps near vehicles (including aircraft) equipped with a transmitter, protect the blasting caps by placing them in a metal can with a snug-fitting cover (½ inch or more of cover overlap). Do not remove blasting caps from their containers near an operating transmitter unless the hazard has been judged acceptable.

Keep electric blasting caps at least 155 meters from energized power lines. If using electric blasting caps near power lines, temporarily cut the power to the lines

during blasting operations.

Always use at least the minimum current required to fire electric blasting caps.

Always check circuit continuity of electric blasting caps before use.

Cover connections between blasting cap leads and firing wires with insulating tape, not the cardboard spool.

Remove firing wire loops and, if practical, bury blasting wires.

b. Time Fuse and Detonating Cord.

(1) Time Fuse.

Always conduct a test burn of at least three feet for each roll of time fuse. If you do not use the fuse within 24 hours of the test burn, perform another test burn before using the fuse.

Use M2 crimpers to cut time fuse. If serviceable M2 crimpers are not available, use a sharp knife to cut fuse. Be sure to cut the fuse end squarely. Make the cut on a nonsparking surface, such as wood. A rough or jagged-cut fuse can cause a misfire.

Avoid cutting the fuse until you are ready to insert it into the igniter and blasting cap.

To avoid problems from moisture infiltration, never use the first or last 6 inches of time fuse from a new or partial roll.

Avoid sharp bends, loops, and kinks in time fuse. Avoid stepping on the fuse. Any of these conditions or actions can break the powder train and result in a misfire.

(2) Detonating Cord.

Do not carry or hold detonating cord by placing it around your neck.

To avoid problems from moisture infiltration, never use the first or last 6 inches of detonating cord from a new or partial roll.

Avoid sharp bends, loops, and kinks in detonating cord. Avoid stepping on the cord.

Any of these conditions or actions can change the path of detonation or cause the cord to cut itself.

c. Plastic and Sheet Explosives.

Always cut plastic and sheet explosives with a sharp

knife on a nonsparking surface.

Never use shears.

Avoid handling explosives with your bare skin as much as possible.

d. Picric Acid. Picric acid degrades with time. Do not use picric acid if its container is rusted or corroded. A rusty or corroded container indicates the explosive is unstable.

WARNING

Do not handle picric acid. Notify EOD for disposition.

e. Commercial Explosives. Commercial dynamite is sensitive to shock and friction and is not recommended for use in combat areas. Do not use old, commercial dynamite because it is extremely sensitive and very unstable. Follow the procedures in TM 9-1300-206 or the manufacturer's recommendations to destroy aged commercial dynamite. When commercial dynamite freezes, it becomes covered with crystals and is very unstable. Do not use frozen dynamite. Commercial dynamite containing nitroglycerin requires special handling and storage. Rotate commercial dynamite in storage to prevent the nitroglycerin from settling to the bottom of

the explosive.

6-3. Boreholes. Do not leave any void spaces in boreholes, especially in quarrying operations. A secondary explosion can result from a borehole with voids between loaded explosives. After the first blast, it may take up to 15 minutes for such an explosion to occur. Tamp all voids with appropriate material. When using springing charges to dig boreholes, allow at least 2 hours for boreholes to cool between placing and firing successive springing charges, or cool the boreholes with water or compressed air to save time.

6-4. Toxicity. Most military explosives are poisonous if ingested and will produce lethal gases if detonated in confined areas such as tunnels, caves, bunkers, and buildings. Allow sufficient time for blast fumes, dust, and mists to clear before inspecting or occupying a blasting area. TNT is extremely poisonous; avoid using TNT to blast in enclosed areas. Avoid touching sensitive areas of your body, such as around the face and groin, when working with explosives. Wash your hands after working with explosives, especially before consuming food.

6-5. Natural and Physical Properties.

a. Lightning. Lightning is a hazard to both electric and

nonelectric blasting charges. A lightning strike or nearby miss is almost certain to initiate either type of system. If lightning strikes occur, even far away from the blasting site, electrical firing circuits could be initiated by high, local earth currents and shock waves resulting from the strikes. These effects are increased when lightning strikes occur near conducting elements, such as fences, railroads, bridges, streams, underground cables or conduits, and in or near buildings. The only safe procedure is to suspend all blasting activities during electrical storms or when an electrical storm is imminent.

b. Static Electricity. Though rare, electric blasting caps can possibly be initiated by static electricity. If possible, avoid using electric blasting caps if static electricity is a problem. Exercise extreme caution when working with explosives in cold, dry climates or when wearing clothing and equipment that produce static electricity, such as clothing made of nylon or wool. Before handling an electric blasting cap, always remove the static electricity from your body by touching the earth or a grounded object. It may be necessary to perform this grounding procedure often in an area where static electricity is a constant problem.

c. Induced Currents. Radio signals can induce a current in electric blasting caps and prematurely

detonate them. Table 6-1 lists the minimum safe distances from transmitters for safe electrical blasting. This table applies to operating radio, radar, microwave, and television transmitting equipment. Keep mobile transmitters and portable transmitters at least 50 meters from any electric blasting cap or electrical firing system. Do not use electric blasting caps within 155 meters of energized power transmission lines.

d. Blast Effects. Personnel in close proximity to explosions may experience permanent hearing loss or other injury from the pressure wave caused by an explosion. Hearing protection should be worn during all blasting operations. Personnel observing minimum safe distances for bare charges (see Table 6-1 and Army Regulation (AR) 385-63) generally will not be affected by blast effects. Refer to AR 385-63, Chapter 18, for additional information on blast effect.

Table 6-1. Safe distances for blasting near radio frequency energy

Average or Peak Transmitter Power (Watts*)	Minimum Safe Distance (Meters)
0 to 29	30
30 to 49	50
50 to 99	110
100 to 249	160
250 to 499	230
500 to 999	305
1,000 to 2,999	480
3,000 to 4,999	610
5,000 to 19,999	915
20,000 to 49,999	1,530
50,000 to 100,000	3,050

*When the transmission is a pulsed- or pulsed, continuous-wave type and its pulse width are less than 10 microseconds, the left-hand column indicates average power. For all other transmitters, including those with pulse widths greater than 10 microseconds, the left-hand column indicates peak power.

e. Missile Hazards. Explosives can propel lethal missiles great distances. The distances these missiles will travel in air depend primarily on the relationship between the missiles' weight, shape, density, initial angle of projection, and initial speed. Under normal conditions, the missile-hazard area of steel-cutting charges is greater than that of cratering, quarrying, and surface charges.

6-6. Underwater Operations.

a. Explosives. Explosives are subject to erosion by water. Unprotected explosives will deteriorate rapidly, reducing their effectiveness. Ensure all exposed explosives are adequately protected when used in water, especially running water.

b. Nonelectric Caps. Nonelectric caps depend on combustion to work properly. Any moisture inside a nonelectric cap may cause a misfire. Because nonelectric blasting caps are difficult to waterproof, aviod using them to prime underwater charges or charges placed in wet boreholes.

c. Time Fuse. Time fuse depends on combustion to burn properly. Time fuse burns significantly faster underwater due to water pressure. Waterproof sealing compounds will not make

a permanent waterproof seal between the fuse and a nonelectric blasting cap. Place the fuse underwater at the last possible moment before firing.

NOTE: If the mission requires using time fuse underwater, then do the test burn underwater.

d. Detonating Cord. Seal the ends of detonating cord with a waterproof sealing compound when using detonating cord for initiating underwater charges or charges that will remain in place several hours before

firing. Leaving a 6-inch overhang in detonating cord normally will protect the remaining line from moisture for 24 hours.

e. M60 Fuze Igniter. The M60 depends on combustion to work properly. Water can penetrate the fuze igniter through the vent hole located in the pull rod. Therefore, if the igniter fails to fire on the initial attempt, it probably will fail on any subsequent attempt after reset. Always use a backup initiation set for underwater demolitions.

6-7. Safe Distances. The following criteria give distances at which personnel in the open are relatively safe from missiles created by bare charges placed on the ground, regardless of the type or condition of the soil (AR 385-63). Table 6-2 lists safe distances for selected charge weights. The following general rules apply:

Charges of Less than 27 Pounds. The minimum missile hazard distance is 300 meters.

Charges of More than 27 Pounds But Less Than 500 Pounds. Use the distances in Table 6-2.

Charges More than 500 Pounds. Use the following formulas:

$$Safe\ Distance\ (meters) = 100\sqrt[3]{Pounds\ of\ Explosive}$$

$$Safe\ Distance\ (feet) = 300\sqrt[3]{Pounds\ of\ Explosive}$$

Missile-Proof Shelters. A missile-proof shelter can be as close as 100 meters from the detonation site provided it is strong enough to withstand the heaviest possible missile resulting from the demolition.

Charges Fixed to Targets. When charges are fixed to targets and not simply placed on the ground, use the safe distances specified in Tables 6-2 or 6-3, whichever is farthest.

Table 6-2. Safe distances for personnel (near bare charges)

Explosive Weight (Pounds)	Safe Distance		Explosive Weight (Pounds)	Safe Distance	
	Feet	Meters		Feet	Meters
27 or less	985	300	175	1,838	560
30	1,021	311	200	1,920	585
35	1,073	327	225	1,999	609
40	1,123	342	250	2,067	630
45	1,168	356	275	2,136	651
50	1,211	369	300	2,199	670
60	1,287	392	325	2,258	688
70	1,355	413	350	2,313	705
80	1,415	431	375	2,369	722
90	1,474	449	400	2,418	737
100	1,526	465	425	2,461	750
125	1,641	500	500	2,625	800
150	1,752	534			

Table 6-3. Safe distances for personnel (charges on target)

Serial	Charge Type	Target	Charge Size	Radius of Danger Area (m)	Remarks
a	b	c	d	e	f
1	Blasting caps Primers Detonating cord (in the open)	—	—	20	For service personnel under supervision. Applicable to all serials.
2	Cutting	a. Trees	Any	300	
		b. Concrete columns and beams	Any	500	—
		c. Metal girders and plates, guns, and so forth	Any	1,000	Fragments may fly up to 1,000 meters in all directions.
3	Concussion	Buildings and AFV	Any	1,000	If personnel are wearing helmets, you may reduce the safe distance to 500 meters. Consider the strong blast effect when considering buildings as potential blast shelters.
4	Cratering	Roads and airfields	a.. Up to 2 kg	100	
			b. Up to 30 kg	300	
			c. Over 30 kg	500	
5	Mines	Piers Abutments Retaining walls	Any	500	
6	Borehole	Rock Masonry Concrete Brick	Any	300	
7	Breaching	Reinforced-concrete beams and slabs Mass-concrete walls and obstacles	Any	1,000	If personnel are wearing helmets, you may reduce the safe distance to 500 meters. Consider the strong blast effect when considering buildings as potential blast shelters.
8	Shaped	Concrete Steel	Any	1,000	When these charges are fired into the ground vertically, you may reduce the safe distance to 300 meters.
9	Bangalore Torpedo	Wire obstacles	—	a. All right angles to axis, 1,000 meters	
			—	b. In the line of the axis, 200 meters for standing personnel and 100 meters for prone personnel	
10	M180	Roads and airfields	1-15 kits	1,200	Fragments may fly up to 1,000 meters in all directions.

NOTES:
1. The air clearance required is the ground safety distance plus 500 meters above the explosive area.
2. The ship clearance required is the same distance as for the ground safety distance.

Note that these distances depend on the target configuration, not quantity of explosive.

Section II. Misfire Procedures

6-8. Nonelectric Misfires.

a. Causes.

Moisture in the time fuse, detonating cord, or explosives.

Time fuse not seated completely in blasting cap or in fuse igniter.

Breaks in time fuse or detonating cord.

Jagged or uneven ends on time fuse.

Blasting caps not seated securely in cap well or explosive.

Loose or improper detonating-cord installation.

Debris in the blasting cap.

Commercial blasting caps were not strong enough to detonate military explosives.

b. Prevention. You can minimize nonelectric misfires by taking the following precautions:

Prepare and place all primers properly.

Load all charges carefully.

Detonate charges with the proper techniques.

Use dual-initiation systems and, if possible, dual firing systems.

Use detonating cord for underground demolitions. Do not bury caps!

Perform tamping operations with care to avoid damaging prepared charges.

Avoid crimping blasting caps onto time fuse in the rain; seek a covered area out of the rain.

Ensure you completely seat time fuse when installing it into a blasting cap or fuse igniter.

c. Clearing Procedure.

The soldier who placed the charges should investigate and correct any problems with the demolition.

After attempting to fire the demolition, delay investigating any detonation problem for at least 30 minutes plus the time remaining on the secondary. Tactical conditions may require investigation prior to the 30-minute limit.

For above-ground misfires of charges primed with

blasting caps, place a primed, l-pound charge next to the misfired charge and detonate the new charge. Each misfired charge or charge separated from the firing circuit that contains a blasting cap requires a 1-pound charge for detonation. Do not touch scattered charges that contain blasting caps; destroy there in place. For charges primed with detonating cord, use the procedures in paragraph 6-10 (page 6-10).

For a nonelectric cap that has detonated but failed to initiate a detonating-cord branch line, line main, or ring main, attach a new cap to the detonating cord, and then move to a safe place.

For buried charges, remove the tamping to within one foot of the misfired charge.

Constantly check depth while digging to avoid striking the charge. When within 1 foot of the misfired charge, place a primed, 2-pound charge on top of the original charge and detonate the new charge. If digging over the original charge is impractical, dig a new borehole of the same depth beside the original hole, l-foot away. Place a primed, 2-pound charge in the new hole and detonate the new charge.

6-9. Electric Misfires.

a. Causes.

Inoperable or weak blasting machine or power source.

Improper operation of blasting machine or power source.

Defective or damaged connections. (Short circuits, breaks in the circuit, or too much resistance in the electrical wiring are common conditions resulting in misfires.)

Faulty blasting caps.

Blasting caps made by different manufacturers in the same circuit.

Power source inadequate for the number of blasting caps in the circuit (too many caps, too small a blasting machine).

b. Prevention. Assign one individual the responsibility for all the electrical wiring in a demolition circuit. This individual should do the following:

Perform all splicing.

Install all blasting caps in the firing circuit. Do not bury caps!

Make all of the connections between blasting cap wires, connecting wires, and firing wires.

Inspect system for short circuits.

Avoid grounding out the system.

Ensure the number of blasting caps in any circuit does not exceed the rated capacity of the power source.

c. Clearing Procedure. Use the following procedures to clear electric misfires:

Make another attempt to fire.

Use the secondary firing system, when present.

Check the wire connections, blasting machine, or power-source terminals.

Disconnect the blasting machine or power source and test the blasting circuit. Check the continuity of the firing wire with a circuit tester.

Use another blasting machine or power source and attempt to fire the demolition again, or change operators.

When employing only one electrical initiation system, disconnect the blasting machine, shunt the wires, and investigate immediately. When employing more than one electrical initiation system, wait 30 minutes before inspecting. Tactical conditions may require

investigation prior to the 30-minute limit.

Inspect the entire circuit for wire breaks or short circuits.

If you suspect an electric blasting cap is the problem, do not attempt to remove or handle it. Place a primed, 1-pound charge next to the misfired charge and detonate the new charge.

6-10. Detonating-Cord Misfires.

a. Detonating Cord. If detonating cord fails to function properly, take the following action:

Attach a new blasting cap to the remaining detonating cord, taking care to fasten it properly, and detonate the new blasting cap.

Treat branch lines in the same manner as noted above.

b. Detonating-Cord Priming. If the detonating cord leading to the charge detonates but fails to explode the charge, take the following action:

Do not investigate until the charges have stopped burning. Wait 30 minutes if the charge is underground.

Reprime and attempt to detonate the charge.

Scattered charges that do not contain blasting caps may be collected and detonated together.

For underground charges, dig to within one foot of the charge; place a primed, 2-pound charge on top or to the side of the charge; and detonate the new charge.

Section III. Transportation and Storage Safety

6-11. Transportation.

a. Regulations. Both military and commercial carriers are subject to regulations when transporting military explosives and other dangerous military materials within the United States.

AR 55-355 covers the transportation of explosives. When transporting explosives outside the United States, follow the regulations from the host countries as well. TM 9-1300-206 contains minimum safety requirements for handling and transporting military explosives and ammunition.

All explosives transport personnel must learn the local procedures and safety requirements.

b. Safety Procedures. The commander should assign a primary and assistant operator to each vehicle transporting explosives on public highways, roads, or

streets. Whenever transporting explosives locally, operators must observe the following safety rules:

(1) Vehicles.

Ensure vehicles are in good condition. Inspect all vehicles intended for hauling explosives before loading any explosives. Pay particular attention to protecting against any short circuits in the electrical system.

When using vehicles with steel or partial-steel bodies, install fire-resistant and nonsparking cushioning to separate the explosives from the metal truck components.

Do not load vehicles beyond their rated capacities when transporting explosives.

Cover open-body vehicles hauling explosives with a fire-resistant tarpaulin.

Mark all vehicles transporting explosives with reflective placards indicating the type of explosives carried (TM 9-1300-206, Chapter 6).

Use demolition transports for explosives only. Do not carry metal tools, carbides, oils, matches, firearms, electric storage batteries, flammable substances, acids, or oxidizing or corrosive compounds in the bed or body of any vehicle transporting explosives.

Equip vehicles transporting explosives with not less than two Class 1-BC fire extinguishers for on-post shipments. Place the extinguishers at strategic points, ready for immediate use.

Keep vehicles away from congested areas. Consider congestion when parking.

Operate vehicles transporting explosives with extreme cam. Do not drive at a speed greater than 35 miles per hour. Make full stops at approaches to all railroad crossings and main highways. This does not apply to convoys or crossings protected by guards or highway workers (flaggers).

Keep flames at least 50 feet from vehicles or storage points containing explosives.

(2) Cargo (Explosives).

Never leave explosives unattended.

Never mix live and inert (dummy) explosives.

Secure the load of explosives in the transport to prevent shifting during transport.

Transport blasting caps separately from other explosives. Do not transport blasting caps or other

initiators in the same vehicles carrying explosives. If both blasting caps and explosives must be carried in the same vehicle, separate blasting caps from the other explosives by carrying the caps in a closed metal container in the cab of the transport.

No persons other than the primary and the assistant operators will ride on or in a truck transporting explosives. Do not refuel a vehicle while carrying explosives except in an emergency.

(3) Fire. If fire breaks out in a vehicle transporting explosives, take the following actions:

Try to stop the vehicle away from any populated areas.

Stop traffic from both directions. Warn vehicle drivers and passengers and occupants of nearby buildings to keep at least 2,000 feet away from the fire. Inform police, fire fighters, and other emergency-response personnel that the cargo is explosives.

If the fire involves only the engine, cab, chassis, or tires, make an effort to extinguish the fire with fire extinguishers, sand, dirt, or water. If the fire spreads to the body of the transport or the cargo, stop fighting the fire and evacuate to a distance of at least 2,000 feet.

Do not attempt to extinguish burning explosives

without expert advice and assistance.

6-12. Storage Safety.

a. Magazines. There are two types of magazines: permanent and temporary. Although permanent magazines are preferred, temporary or emergency magazines are frequently required when permanent construction is not possible. Field Manual (FM) 9-6 and TM 9-1300-206 give details on magazine storage of explosives. Consider the following when constructing magazines:

(1) Permanent.

(a) Placement. Consider acceptability of magazine locations based on safety requirements, accessibility, dryness, and drainage. Safety and accessibility are the most important. An ideal location is a hilly area where the height of the ground above the magazine provides a natural wall or barrier to buildings, centers of communication, and other magazines in the area. Hillside bunkers are not desirable because adequate ventilation and drainage are often difficult to achieve. Clear brush and tall grass from the site to lessen the danger of fire.

(b) Lightning protection. All magazines must have a grounded, overhead lightning-rod system.

Connect all metal parts (doors, ventilator, window sashes, reinforcing steel, and so forth) to buried conduits of copperplate or graphite rods in several places.

(c) Barricades. Install barricades around magazines; that is, there must be a substantial obstacle between magazines and inhabited buildings. For certain explosives, effective natural or artificial barricades reduce the required safe distance between magazines and railways and highways by one half. The use of barricades permits the storage of larger quantities of explosives in any given area.

Although barricades help protect magazines against explosives and bomb or shell fragments, they do not safeguard against pressure damage. TM 9-1300-206 gives more specific guidance on barricades.

(d) Security. Place guards at all magazines to prevent unauthorized personnel from gaining access to magazine facilities.

(2) Temporary.

(a) Placement. When permanent magazine construction is not possible, create temporary magazines by placing explosives on pallets to

accommodate ventilation. Store the pallets in a well-drained bunker. Excavate the bunker in a dry area and revet the bunker with timber to prevent collapse. Alternatives are an isolated building or a light, wooden-frame house with a wedge-type roof covered with corrugated iron or tent canvas.

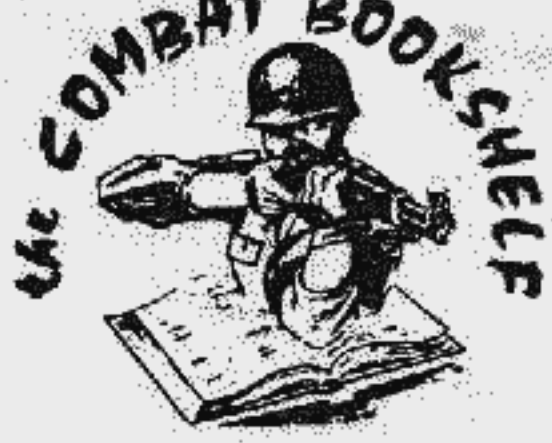
(b) Identification. Mark field-expedient storage facilities on all four sides with signs (TM 9-1300-206).

b. Temporary Storage. When necessary, store limited supplies of explosives in covered ammunition shelters. Ensure the temporary facilities are separated adequately to prevent fire or explosion from being transmitted between shelters. Piles of temporarily stored explosives should contain no more than 500 pounds each and be spaced no closer than 140 feet. Pile explosive components separately. Keep explosives, caps, and other demolition materials stored in training areas in covered ammunition shelters and under guard at all times. Local safety standing operating procedures (SOPS) and TM 9-1300-206, Chapter 4, are guides for temporary storage operations.

BACK TO COMMERCIAL EXPLOSIVES

CIA

IMPROVISED SABOTAGE DEVICES



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INTRODUCTION

For quite a few years now, considerable amounts of time, effort, and money have been expended on improving older sabotage devices and accessory gear and in developing new and better items. As a result, a wide variety of manufactured explosive and incendiary items is available for use.

At the same time a somewhat smaller effort has been devoted to improvising and testing homemade or field expedient devices and techniques for accomplishing similar results.

Since the manufactured, precision devices almost always will be more effective, more reliable, and easier to use, why spend time on improvising field expedients to do the job?

For one thing shelf items will just not be available for certain operations for security or logistical reasons. In these cases the operator will have to rely on materials he can buy in a drug or paint store, find in a junk pile, or scrounge from military stocks.

Secondly, many of the ingredients and materials used in fabricating homemade items are so commonplace or innocuous they can be carried without arousing suspicion. The completed item itself often is more easily concealed or camouflaged.

In addition, the field expedient item can be tailored for the intended target, thereby providing an advantage over the standard item in flexibility and versatility.

While most of the pertinent information on sabotage shelf items is available in catalogues and other publications, much of the improvisation know-how has remained in the minds or files of a few individuals.

It is the intent of this manual to consolidate and bring up to date a selected body of this information and make it available for wider use.

The devices and techniques included have been selected because they have been well proved out and because they are practical, versatile, and not too difficult to do. Other techniques have been omitted because they are too unreliable or are just too hazardous to attempt except under the most carefully controlled conditions.

The techniques described are not so complex as to require a chemical laboratory or machine shop; however, many of them do assume access to basic demolitions and incendiary supplies, such as explosives, time (safety) fuse, detonating cord, blasting caps, and flammable materials, and to a few household tools.

This manual is not intended to stand completely on its own as a substitute for instruction, nor is it a text on basic demolitions. Its chief value should be to aid an instructor who already has a working knowledge of the subject in his training of action personnel. It also will serve as a refresher and guide to individuals who have been trained in these techniques but whose facility has declined from disuse.

EXPLOSIVES FOR SABOTAGE

Commercial and military explosives of one sort or another are in use around the globe. By far the most desirable ones for sabotage purposes are the military plastic explosives and TNT.

Plastic explosives vary in composition and go by different names. The U.S. military has two versions: C-3 and C-4. The British call theirs PE-2 and the Italians T-4. Other names used are RDX and, especially in Europe, Hexagen and Cyclonite.

TNT may be called by its full chemical name, Trinitrotoluene, or it may be referred to as Tolite, Trotyl, or TOL.

Both plastic explosives and TNT have the advantage of being very powerful while at the same time insensitive and quite safe to handle. Both also will retain their explosive properties after prolonged submersion and thus are excellent for underwater use.

Plastics have an additional characteristic which makes them ideal for many of the improvisations described later. They can be sliced or molded into any desired shape or pressed snugly against an irregular target.

TNT, on the other hand, usually is found in a rigid form -- either pressed or molded. Placement on target is therefore more difficult. Sometimes it is available in flake or powder form. Also, the block form can be safely pulverized. Some of the improvisations employ TNT in the loose state.

Dynamites also are used commercially worldwide and often may be more available than military explosives. They may be effectively employed in sabotage, although they are less potent, less versatile, more sensitive to shock or friction, and may not be waterproof.

If no other sources exist, artillery and mortar shells, bombs, land mines, and other munitions may be cannibalized for the high explosives they contain. These munitions usually contain cast explosives, which require extra strong blasting caps or boosters to detonate. However, some of the simpler cannibalization techniques will be discussed.

How about making your own explosives?

This can be done, and literature is available giving formulas and procedures. Unfortunately, the ones easiest and safest to make are the weaker ones and the least effective for most saborage purposes.

One homemade explosive, using nitrate and oils, will be described.

STANDARD FIRING SYSTEMS

General

Since "good" priming often means the difference between a successful shot and a misfire, or between a low order and a high order detonation, a brief summary of the precautions to take and the pitfalls to avoid might be useful before proceeding to actual improvisations.

Explosives may be detonated electrically or nonelectrically. A nonelectric firing system will consist of a blasting cap, a length of time (safety) fuse or a firing device attached to the cap, and a means of activating the system: match, fuse lighter, delay mechanism, or trip wire. The electric system requires an electric cap which has two wires attached, perhaps additional wire, and a battery or batteries to provide current which activates the cap.

The nonelectric firing system is simple and requires a minimum of equipment. Once initiated, however, it passes from the control of the operator. The electric system can be retained in the control of the operator up to the actual firing. Electric caps also are more waterproof. On the other hand, the electric system is more complicated, employs more equipment, and may require the operator to remain near the scene at the time of firing. In addition, electric systems can be accidentally activated by static electricity and are hazardous to use in some target situations.

With either system, the location of the detonator in the charge has considerable effect on the performance of many devices or techniques. The business end of the blasting cap must be surrounded by the explosive to be detonated and, if plastic, the explosive should be firmly pressed around the cap.

Nonelectric Firing

Time fuse, or safety fuse, which is used in most nonelectric firing systems, is available in a multitude of varieties, both in color and rate of burning.

The only sure way to determine the burning time of any kind, or even roll, of safety fuse is to cut a measured length of it, light it, and time it. The operator can then select a length which will provide the time delay he desires.

Safety fuse is quite susceptible to moisture damage, so it is always a good idea to cut off and discard the first 6 inches or so from the exposed end of a roll.

By all odds, the most frequent cause of misfires in nonelectric systems is failure to seat the blasting cap firmly on the time fuse. Here's the proper way to do it:

After testing the burning rate of the safety fuse being used, cut a desired length of it with a sharp knife or with crimpers. Smooth and compress one end of the fuse by rolling the end between thumb and forefinger. This

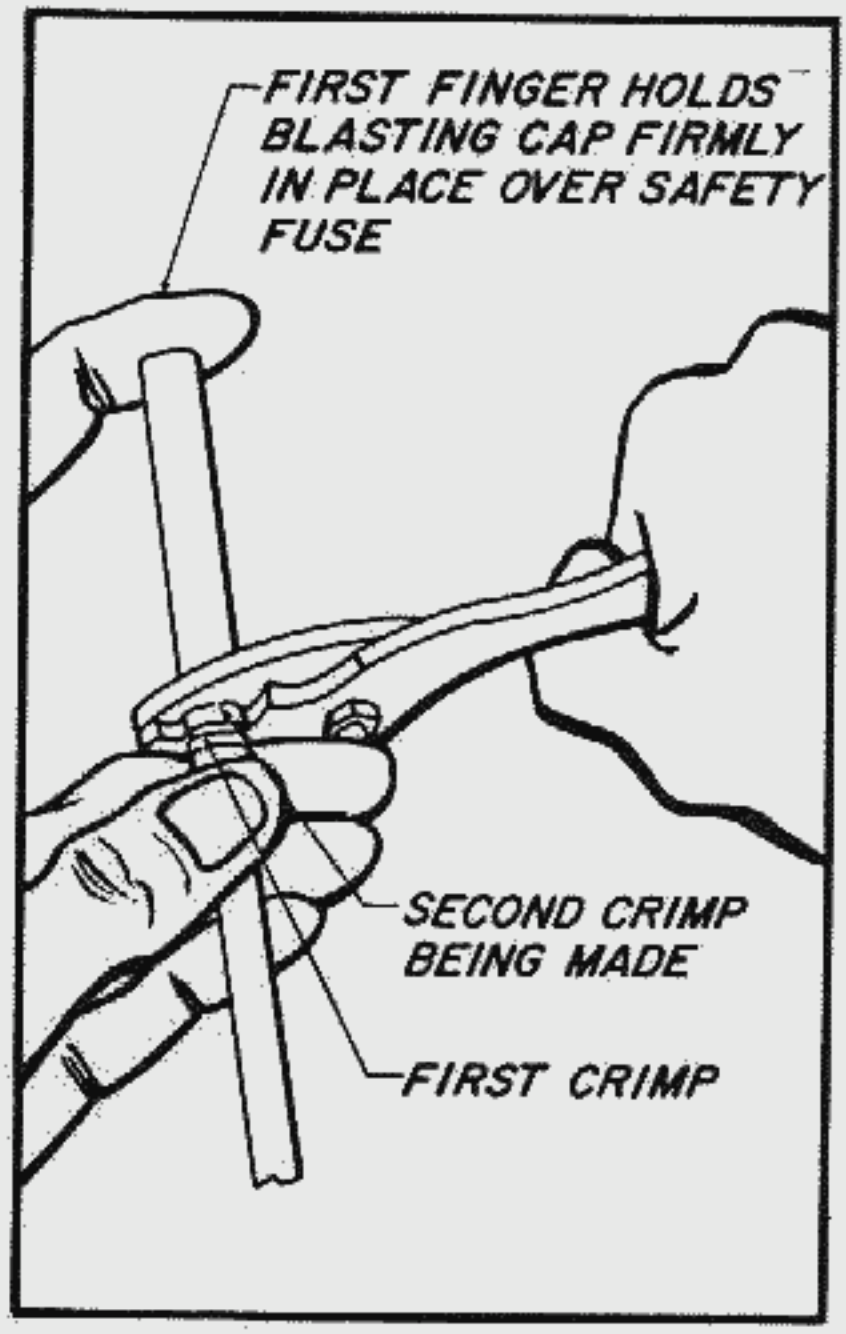


Fig. 1 — Crimping

will make it easier to insert into the cap. Next, insert the prepared end of the fuse firmly into the open end of the blasting cap until it stops. Hold the cap vertically, with the fuse pointing down, and keep it tightly seated by pressing down with the forefinger while gripping the fuse with other fingers of the same hand (see Figure 1). Now crimp the cap to the fuse at a point near the open end of the cap.

The easiest way to light safety fuse is with a mechanical fuse lighter, widely used in military services, or with special hot-burning fuse lighting matches. If ordinary matches must be used, here's the surest way to do it:

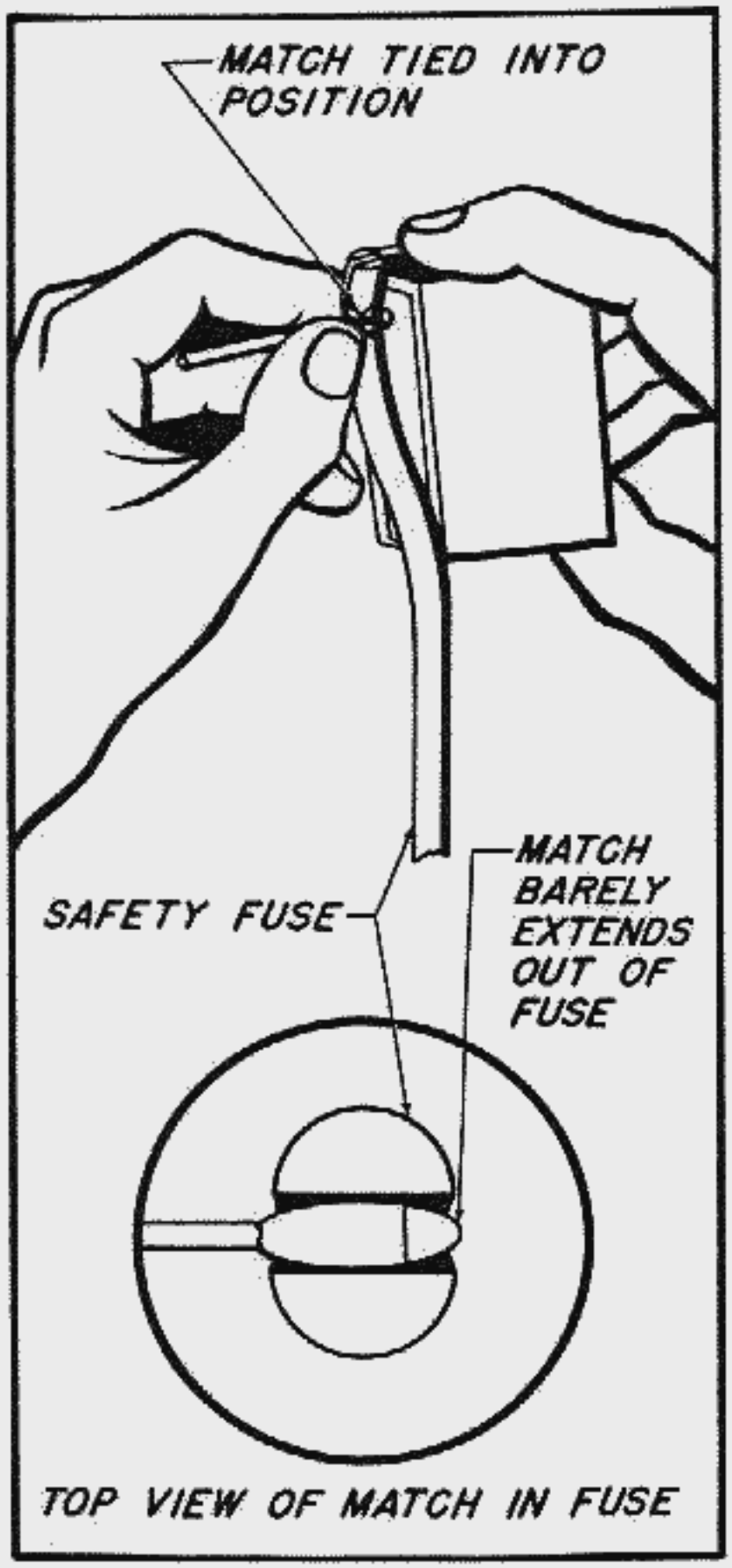


Fig. 2 — Lighting Safety Fuse

Make a half-inch split in the end of the fuse through the center of the powder train. Break off a match head and insert it into the split so that the match head is in intimate contact with the powder but with its tip protruding sideways from the split. The match head should be firmly held or tied in this position (see Figure 2) for igniting against the matchbox or folder striker board.

Electric Firing

The most frequent troubles in electric firing are insufficient battery power, or shorts or breaks in the circuit.

An ordinary flashlight battery is strong enough to fire a single electric blasting cap if the current has to travel only through the cap wires or a short length of additional wire. The amount of extra power required will depend upon the type and length of firing wire, the number of caps and the method of connecting them.

Electric firing circuits always should be tested for breaks and sufficient power before the blasting cap is attached. This can be done by touching the bare ends of the two wires, which will be later connected to the blasting cap, to the bottom and metal side of a flashlight bulb. If the bulb lights up the circuit is good and the battery strong enough. If it glows only faintly or not at all the system probably will not work.

After testing, always be sure the power source is disconnected before attaching the blasting cap.

Primacord

Primacord, or detonating cord, differs from time fuse in that it detonates practically instantaneously along its entire length rather than burning progressively and relatively slowly.

Its chief use is to tie together separate charges for simultaneous detonation.

Since the shock of a single strand of primacord is not powerful enough to detonate most explosives, a knot must be tied at the end to

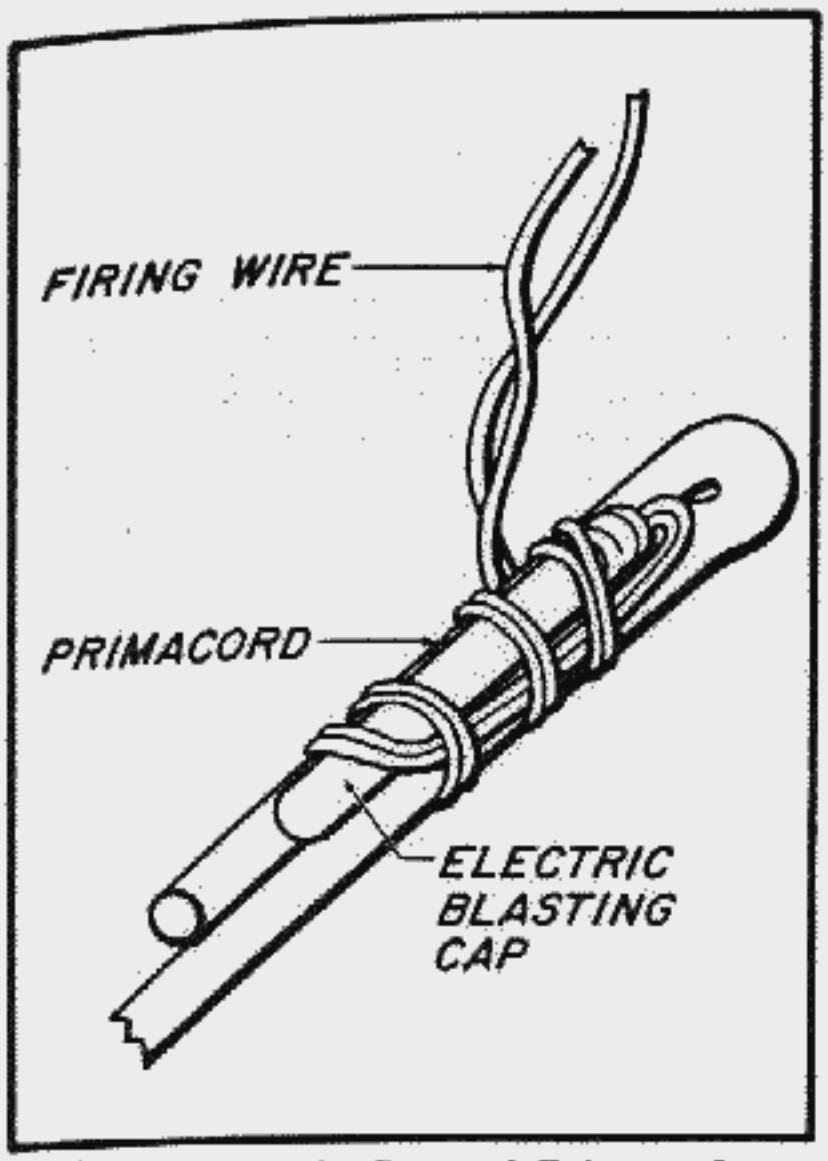


Fig. 3 — Electric Cap and Primacord

concentrate explosive force within the charge to be detonated. A properly tied knot, securely buried, is sufficient to detonate plastic explosives.

A blasting cap is necessary, however, at the point of initiation of the firing system to detonate the cord itself. The shock will then be carried to each charge attached to the system. The blasting cap always should be securely fastened, taped or tied, to the primacord, with the explosive end of the cap pointing down the line toward the charges to be fired (see Figure 3).

When laying out a firing system using primacord, avoid sharp angles or bends in the lines. The shock wave in the cord as it detonates will turn corners of 90° and continue. If the angle around a bend or to a branch line is sharper than 90°, the detonation may fail at that point.

A proper main line and branch line hookup is illustrated in Figure 4.

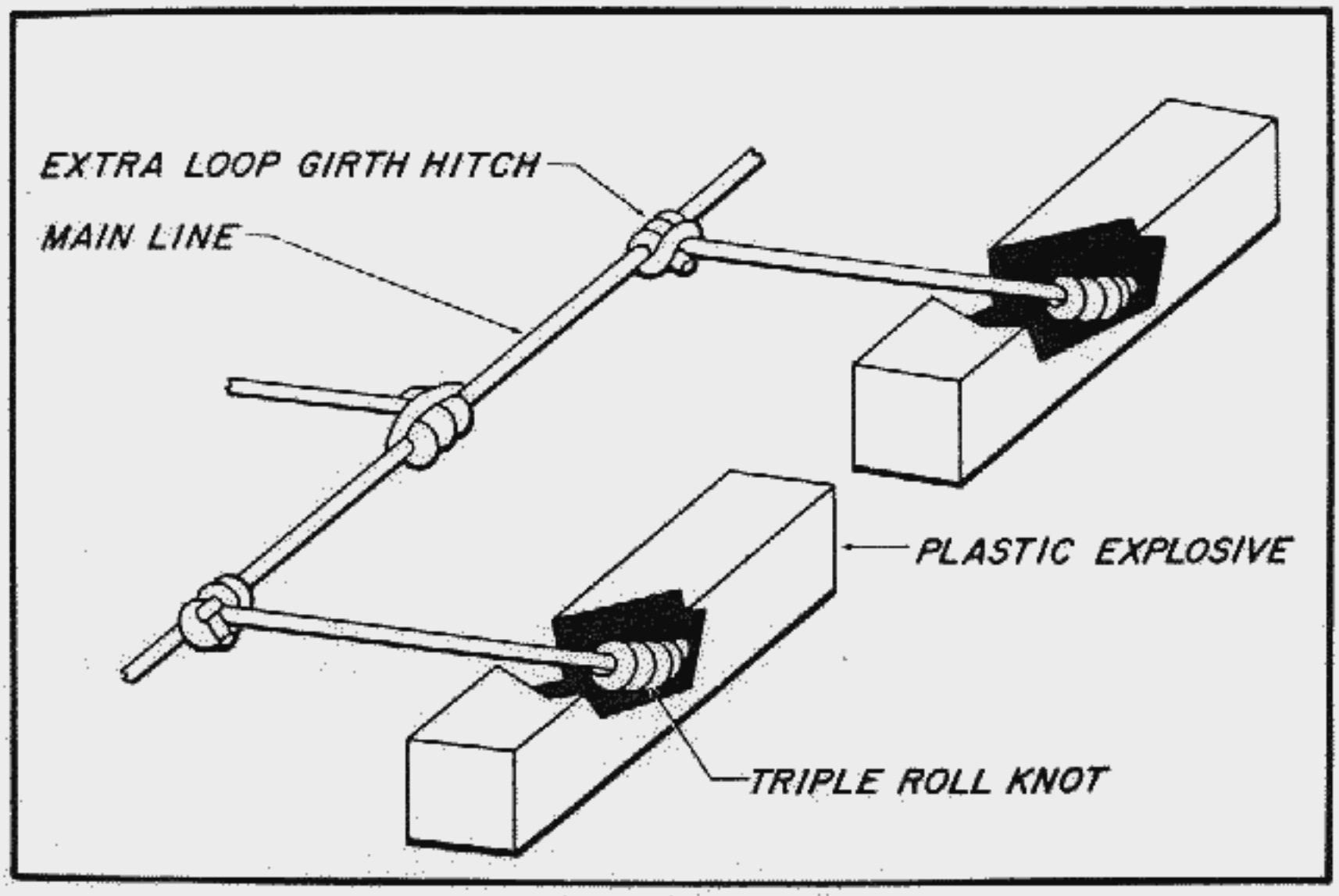


Fig. 4 — Primacord Branch Line System

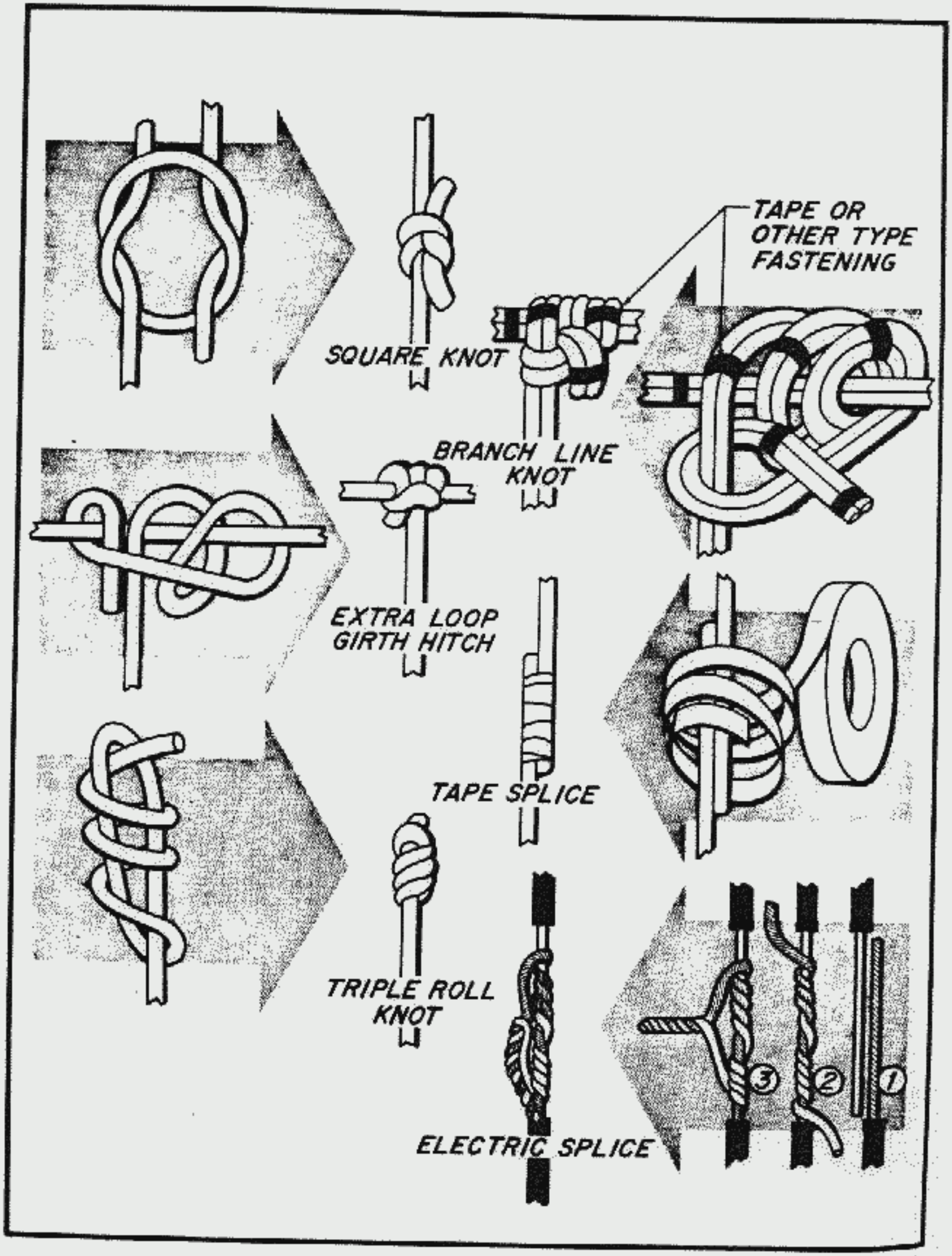


Fig. 5 — Splices and Knots

In priming plastic explosives with primacord, the triple roll knot (see Figure 5) is a good one to use. Three turns of the cord are concentrated in one tight knot, insuring detonation of the charge.

A good knot for tying a branch line to a main line is the girth hitch with an extra turn around the main line (see Figure 5). The knot should be pulled up snugly and the branch line extended at 90^{o}.

Splices in primacord are best made with a square knot (see Figure 5). It may be a good precaution to tape or tie the knot to prevent loosening, particularly if the cord is stiff or slippery.

IMPROVISED FIRING SYSTEMS

General

Depending upon the purpose and circumstances of the job to be done, the operator will need different ways of setting off his charges. He may need only a short delay, such as may be provided by a piece of time fuse, to permit him to get out of range of the explosion. He may need a reasonably accurate delay of several hours. He may wish to initiate the action instantaneously himself at a precise moment. Or he may wish to have the action initiated by the target.

A number of improvised electrical, mechanical, or chemical means of accomplishing these various purposes are described and illustrated in this section. The techniques presented illustrate different principles which can be employed and by no means exhaust the possibilities.

Electric Pressure Switch

This is a simple device to close an electric circuit and detonate a charge when pressure is applied by a target individual or vehicle.

MATERIALS: Two tin can lids or similar pieces of metal, dry paper, battery, electric wire, electric blasting cap.

PREPARATION:

1. Drive nail holes through one of two flat, shiny tin can lids so that sharp points of metal protrude from the other side.

2. Tightly attach a piece of hookup (small diameter electrical) wire to each lid through a hole punched near the edge.

3. Make a sandwich of the lids, with a piece of dry paper in between completely separating the lids. The lid with the nail holes may be on top or bottom, but the "pips" must point in toward the paper, as shown in Figure 6.

4. Test the device with a battery and flashlight bulb. Pressure on the top lid should push the sharp points through the paper to make contact with the lid below, thus completing a circuit. The amount of pressure

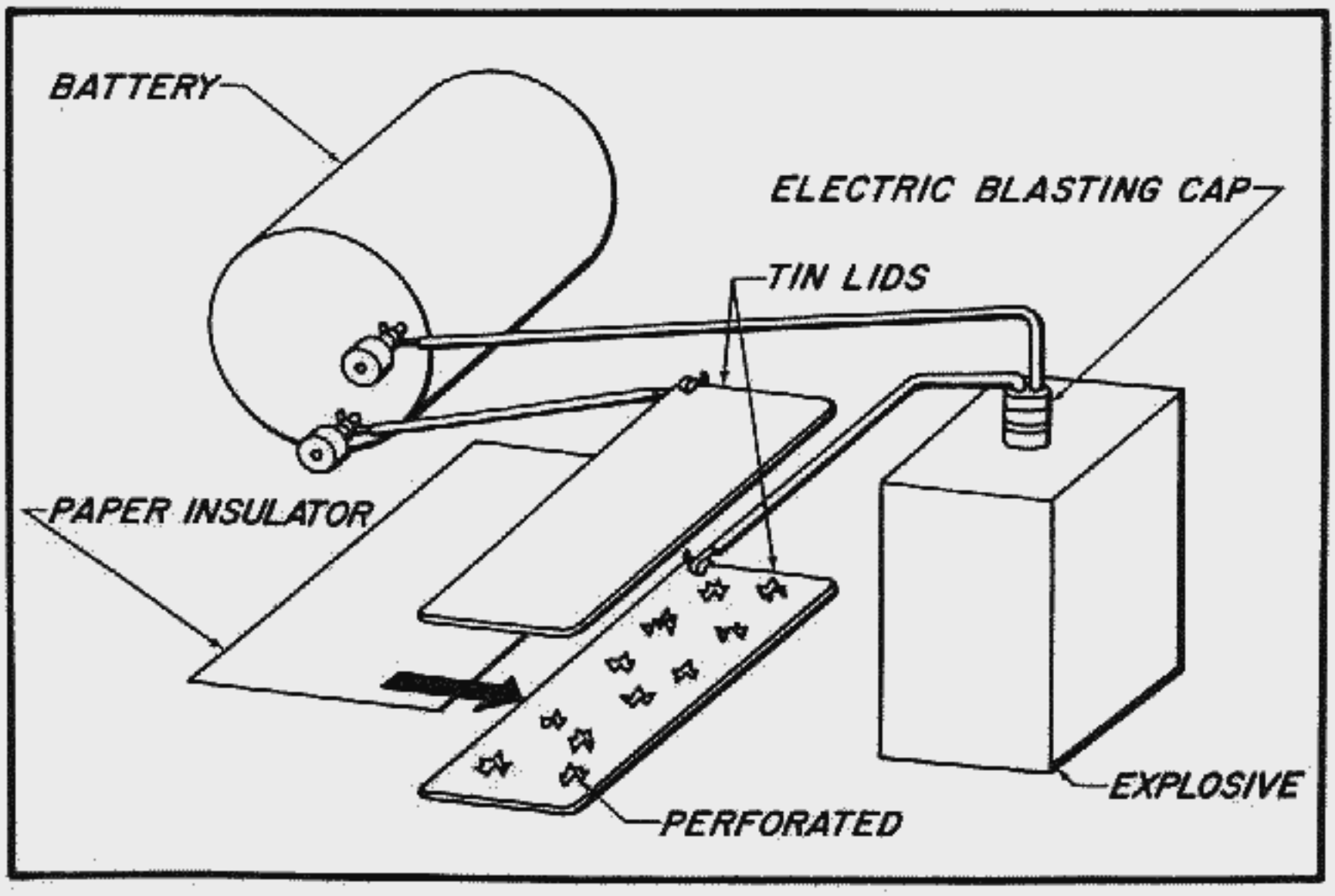


Fig. 6 — Electric Pressure Switch (Lids)

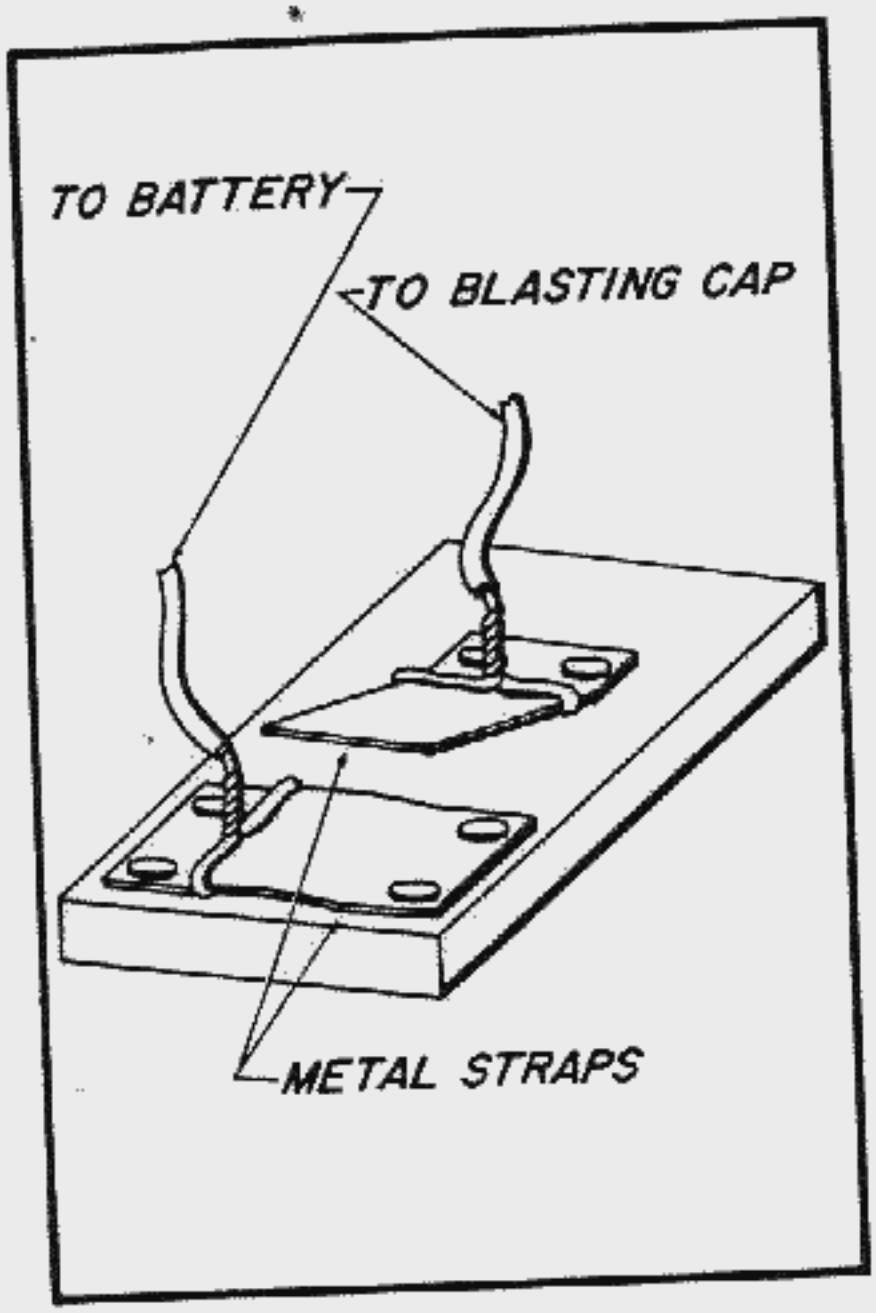


Fig. 7 — Electric Pressure Switch (Straps)

required can be varied by using paper of different types or thickness.

Before using the device in an operation, of course, the piece of test paper will have to be replaced by a fresh, unpunctured one of similar strength. Also, after the switch is positioned, and perhaps concealed, a further test with bulb and battery is necessary to be sure the switch is OPEN before the wires to the blasting cap and charge are connected.

A variation of this system, using two metal straps nailed to a board, is shown in Figure 7.

Water-Drip Electric Delay

This device will close a switch after a short delay. The delay time can be accurately controlled by the amount of water used.

MATERIALS: Tin can, wood scrap, electric wire, battery, electric blasting cap.

PREPARATION:

1. Make a very small hole in the side of the can at the bottom.

2. Use a small piece of wood for a float in the can. Attach a piece of stiff insulated hookup wire to this float so that the wire will extend 2 or 3 inches above the top of the can when the float is resting on the bottom (see Figure 8).

3. Fasten a second piece of insulated electric wire across the middle of the top of the can. Make a loop in the center of this wire and strip the insulation from the loop.

4. Now run the straight wire from the float through the loop of the wire crossing the top of the can. With the float just off the bottom of the can, mark the float wire at the point where it goes through the loop. Remove the insulation from this point on the wire to the top end.

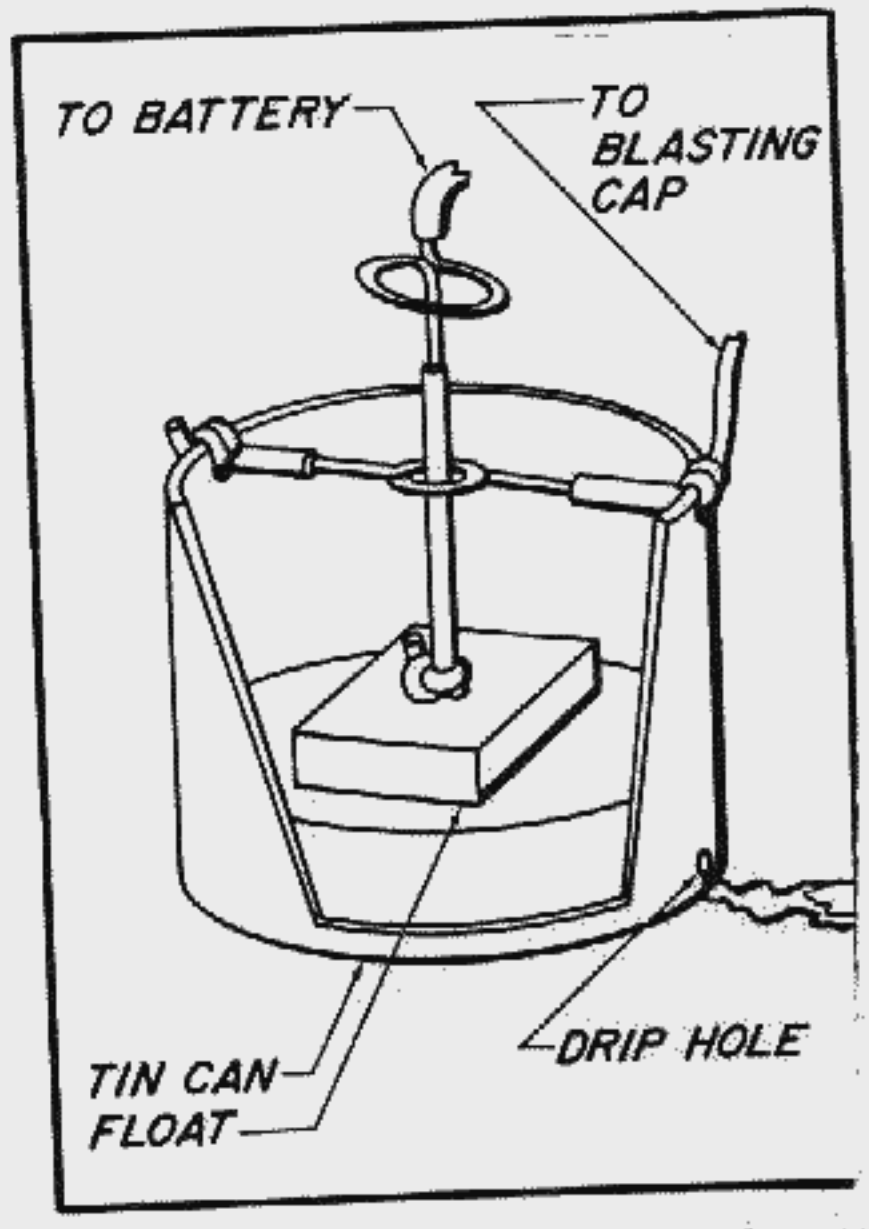


Fig. 8 — Water-Drip Electric Delay

5. Bend a kink or loop in the float wire at the point from which the insulation was removed. This bend should be made so that no matter how the float sinks to the bottom of the can, the bare wire at the bend will contact the uninsulated wire of the loop. Leave enough wire above the kink or loop to attach a hookup wire.

6. Check the operation of the device with a battery and flashlight bulb and determine the proper height to which water should be added in the can for the desired delay. A piece of tape or wax may be used to close the hole and prevent the water from dripping until it is desired to start the delay.

To use, place the delay on a firm, level support and fill with water to the desired level. Check to see that the circuit is open before making the final connection between the battery and blasting cap. After making the final connection, open the drip hole to start the delay.

Expansion Electric Delay

This is a variation of the drip delay and may be more suitable in a situation where leaking water is undesirable. The delay time is not readily varied but normally runs from 1/2 to 2 hours.

MATERIALS: Small bottle or test tube, dried peas, beans, or grain, small piece of cork or wood, battery, electric wire, electric blasting cap.

PREPARATION:

1. Cut a float from cork or wood to a slightly smaller diameter than the test tube or other container to be used.

2. Strip the end of a piece of insulated electrical wire and fasten the bared portion to the top of the float as shown in Figure 9.

3. Pour the required amount of peas, beans, or grain into the container and insert the float as illustrated.

4. Fasten a second hookup wire to the top of the container with a bare section extending across the center of the opening, as shown in Figure 9.

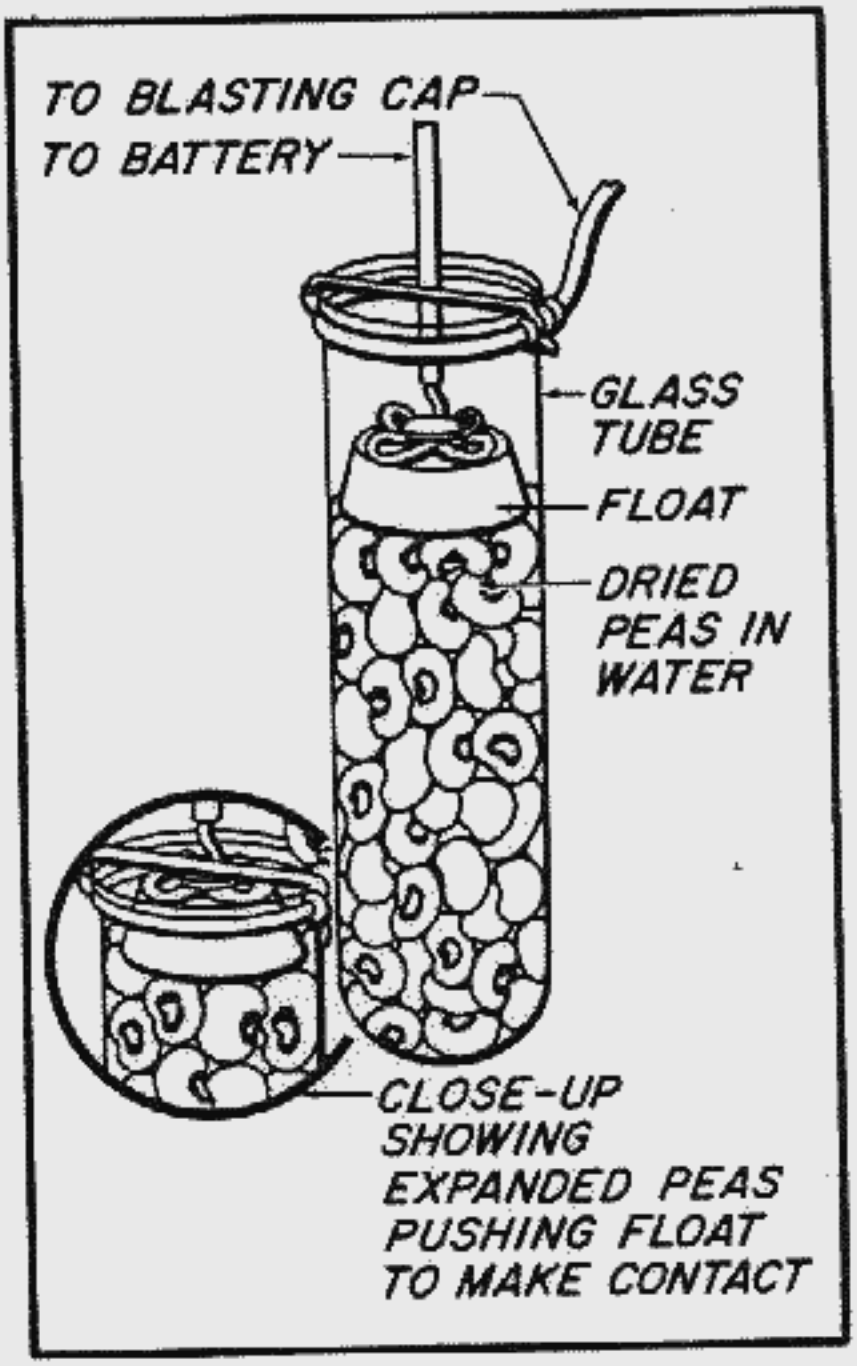


Fig. 9 — Expansion Electric Delay

5. Check the operation of the device by filling the container with sufficient water to cover the dry fill material. As the dried material swells it will push the float to the top of the container and complete the circuit.

6. Test the circuit with a flashlight bulb.

When used in an operation, the container should be securely fastened upright to a stable object. Fresh dry fill material will be required and, as always, the circuit should be tested to see that it is open before the blasting cap is attached.

Pocket Watch Electric Delay

Provides an accurate time delay of up to 11 hours.

MATERIALS: Pocket watch with plastic crystal, small screw, electric wire, battery, electric blasting cap.

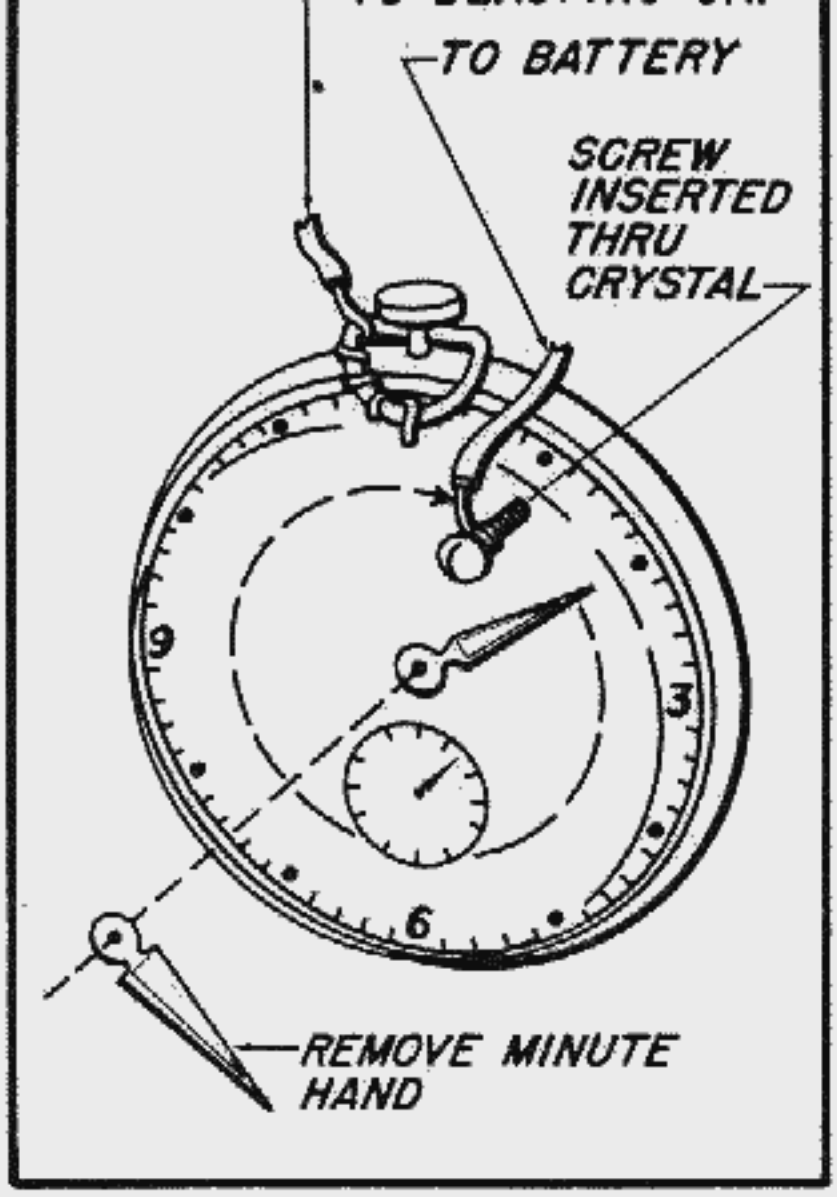


Fig. 10 — Pocket Watch Electric Delay

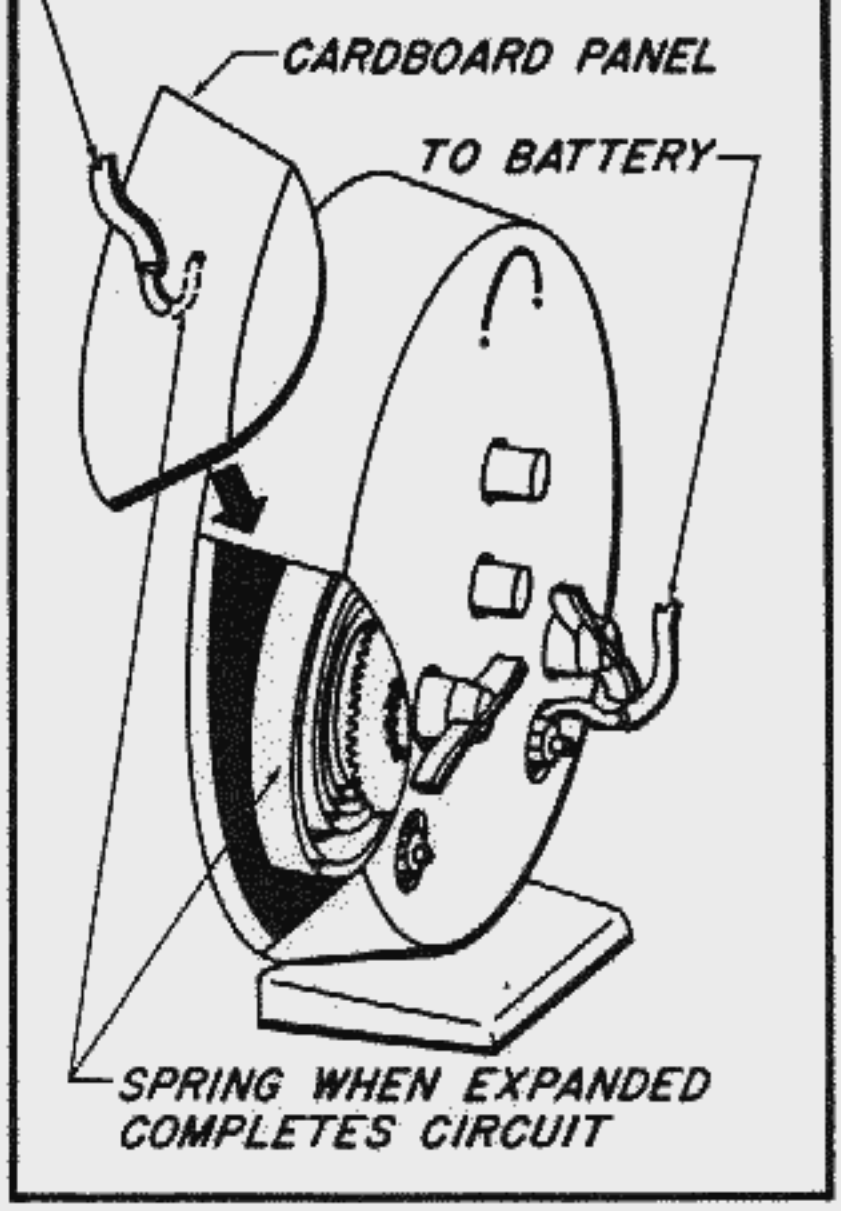


Fig. 11 — Seven Day Electric Delay

PREPARATION:

1. Remove the crystal from the watch.

2. If a delay of less than 55 minutes is desired, remove the hour hand; otherwise, remove the minute hand. (The hand may be broken off, if care is taken not to dislodge the other hand.)

3. Make a small hole in the crystal slightly less than the length of the hand from the center of the crystal. Insert the screw from the front of the crystal and tighten it so that it projects from the concave side. Carefully scrape any paint from the edge of the hand where it will make contact with the screw. Replace the crystal in the watch. See Figure 10.

4. Now turn the hand to see that it contacts the screw. If the hand passes beneath the screw, tighten the screw until it obstructs passage of the hand. However, be sure the screw does not contact the face of the watch (which may be metal).

5. Attach one length of hookup wire to the screw head and another to the winding stem or any other bare metal part of the watch case.

6. Test the device for proper functioning and accuracy of delay.

To use, wind the watch fully and be sure it is running. Set the desired time delay by backing the hand away from the contact screw. Check to be sure the circuit is open before making final connections to battery and blasting cap.

Seven Day Electric Delay

Provides an accurate delay of up to seven days.

MATERIALS: Seven day clock, cardboard or other insulating material, tape or glue, electric wire, battery, electric blasting cap.

PREPARATION:

1. Remove the back of the clock and cut away that part of the housing next to the clock mainspring. See Figure 11.

2. Replace the clock housing and attach one hookup wire tightly to any bare metal part on the outside of the clock.

3. Make a panel from cardboard or other stiff nonconducting material to close the opening in the housing. This should be firmly placed so as to obstruct further expansion of the clockspring as it unwinds.

4. Pierce the cardboard with the bare end of a hookup wire so that the clockspring will make contact with the end of the wire when it unwinds.

5. To preset a desired delay, first wind the clock fully. Push the hookup wire in through the cardboard until the bare end touches the clock spring. As the spring expands, it will push the wire back out through the opening. When the desired delay in days and hours has elapsed, firmly secure the wire at that point with glue or tape. To prevent the preset delay from being dislodged by further pressure from the clockspring, wind the clock a few turns and then stop the clock's movements until it is needed.

To use, wind the clock fully and be sure it is running. The position of the hands does not matter since the delay is based on the unwinding of the spring. Check to make sure the circuit is open before making final connections to battery and blasting cap.

Electric Pull-Release

Initiates an explosion when a trip wire is bumped into, cut or broken.

MATERIALS: Hacksaw blade, table knife or strip of springy steel, board, nails, electric wire, battery, electric blasting cap.

PREPARATION:

1. Anchor the blade or knife firmly at one end of a board, so that it is resting on edge and extending horizontally down the board,

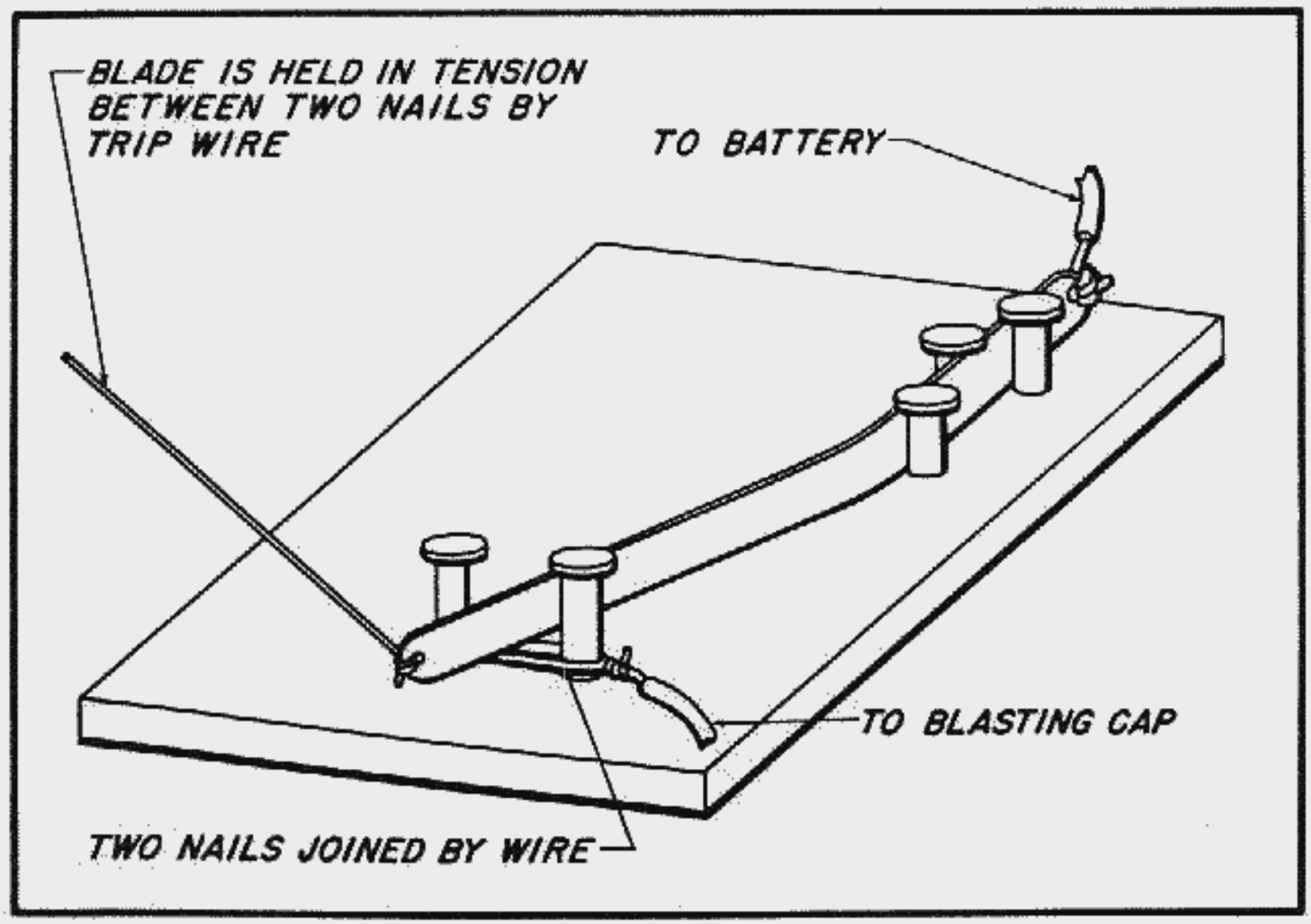


Fig. 12 — Electric Pull-Release

2. Flex the tip of the blade in either direction and drive a nail at that point outside the blade but touching it. Drive a second nail an inch or so (depending upon the flexibility of the blade) on the other side of the blade. If the blade is now released it should rest against the second nail in a slightly flexed condition. See Figure 12.

3. Connect the two nails with a short piece of uninsulated wire so they become a common contact. The connecting wire must be as low on the nails as possible so the blade can swing between the nails and above the wire without touching it.

4. Attach one length of hookup wire to the fixed end of the blade and a second piece to either of the nails.

5. Now test the circuit with battery and flashlight bulb. If the blade is held or secured midway between the two nails the circuit should be open. If the blade is moved to touch either of the nails, the circuit should close.

To set up the device, the mounting board should be firmly fixed or anchored. Attach the trip wire firmly to a fixed position and fasten the other end to the movable end of the hacksaw blade or knife. Adjust the tension of the trip wire until the blade is held midway between the two nails. Check to be sure the circuit is open before making final connection to blasting cap. If the trip wire is pulled or broken the circuit will be closed, firing the blasting cap.

Electric Tilting Mercury Switch

A booby trap device which may be activated by a pull wire or by tilting of object to which applied, such as luggage, door handle, or hinged cover of box.

MATERIALS: Mercury, eye dropper or small glass tube, cork or wood, cement or glue, electric wire, battery, electric blasting cap.

PREPARATION:

1. Seal the narrow end of an eye dropper in an open flame and remove the squeeze bulb from the other end.

2. Pour a few drops of mercury into the dropper.

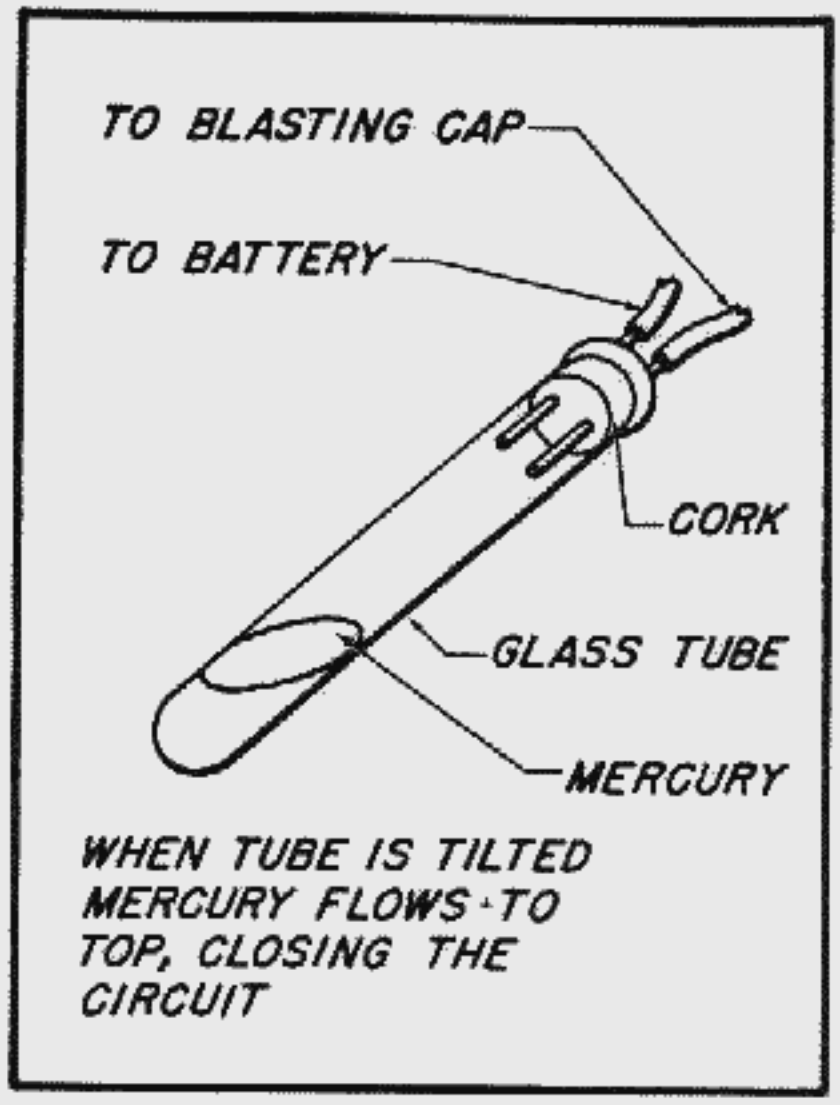


Fig. 13 — Electric Tilting Mercury Switch

3. Fit a cork or wood stopper tightly into the dropper. Make two small holes through the stopper or two grooves along the sides of the stopper through which the bare ends of two pieces of hookup wire can be inserted (see Figure 13). When the mercury is tilted toward the wires it will complete an electrical circuit. When it is tilted toward the other end the circuit will be open. A trip wire also may be used to activate the device.

4. Test the circuit and operation of the device.

To use, secure the device to the object to be booby trapped, with the mercury drained away from the ends of the hookup wires. Check to be sure the circuit is open before making final connections to battery and blasting cap.

Mousetrap Electric Release

This is a booby trap firing device which may be concealed in a cigar box, book, package or under any object heavy enough to hold the arm of the mousetrap in a cocked position.

MATERIALS: Spring mousetrap, electric wire, battery, electric blasting cap.

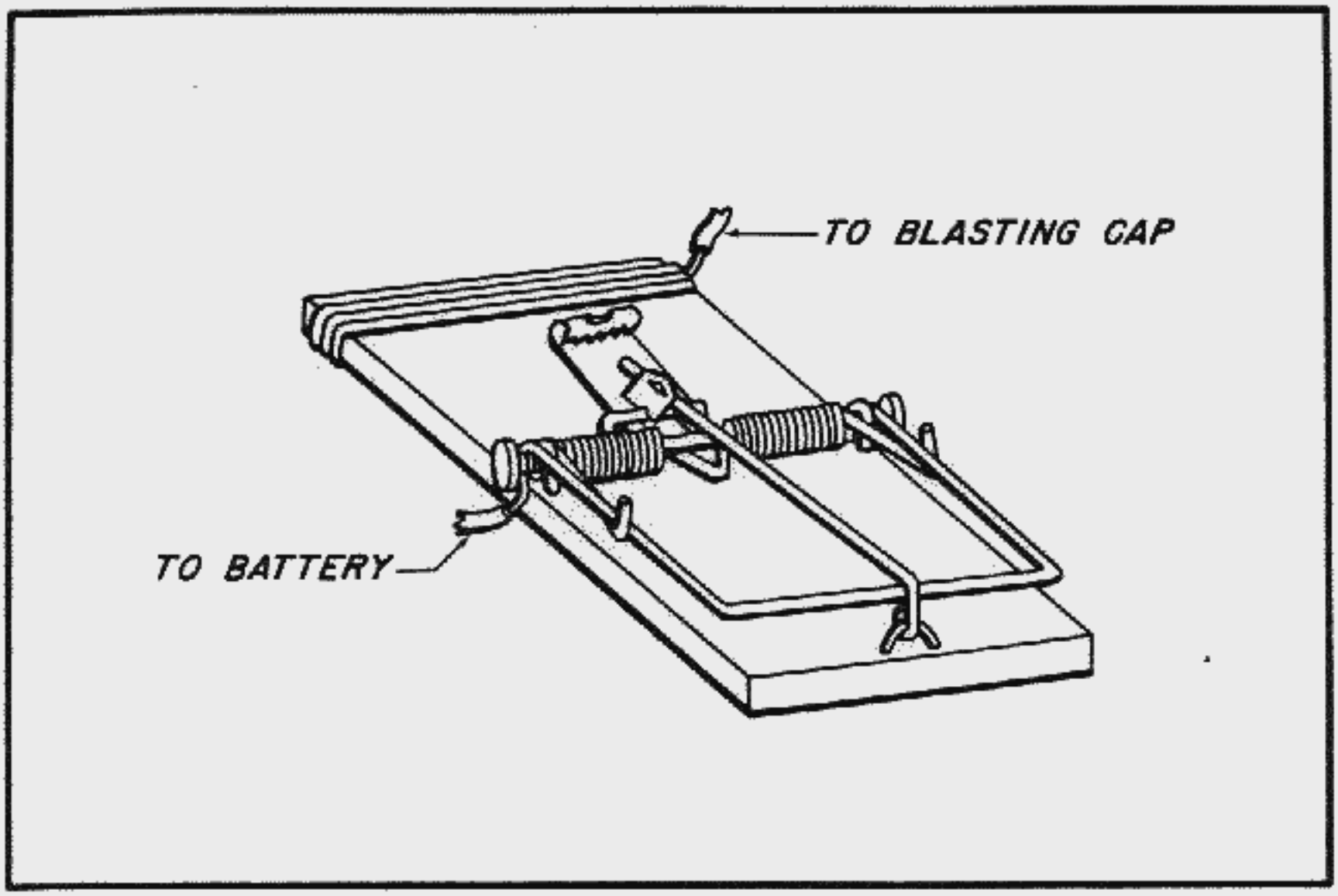


Fig. 14 — Mousetrap Electric Release

PREPARATION:

1. Attach one length of hookup wire firmly to the spring which drives the "catcher" arm of the mousetrap.

2. Strip the insulation from about 6 inches of a second hookup wire and wrap this bared portion tightly around the wooden end of the mousetrap where it will be contacted by the catcher arm when released (see Figure 14).

3. Check the circuit and the operation of the device.

To use, fasten the device securely in place and cock the trap, making sure the lid or weight being used will hold the arm down fully in the cocked position. Check to be sure the circuit is open before making final connections to battery and blasting cap. Removal of the lid or weight will spring the trap and fire the blasting cap.

Electric Pull-Slide Switch

This simple item provides perhaps the best and easiest method of firing a charge electrically by means of a pull wire. It may be rigged so the target trips the wire or it may be controlled by the operator from a safe distance. It is an excellent device to use with bazooka rockets against trucks, tanks, or locomotives.

MATERIALS: Rubber band or other piece of elastic, stick, trip wire or string, electric wire, battery, electric blasting cap.

PREPARATION:

1. Cut two 6 inch lengths of hookup wire and make a 1/4 inch wide loop of bare wire in one end of each.

2. Bend the loops at right angles to the wire and then thread the two wires together by passing the straight end of each wire through the loop in the other. The bare loops should now make contact if the wires are pulled in opposite directions. See Figure 15. (Although the device can be used in this simple condition, it will be more reliable if the following additional steps are taken.)

3. Attach a rubber band to one of the loops and fasten the other end of the rubber band

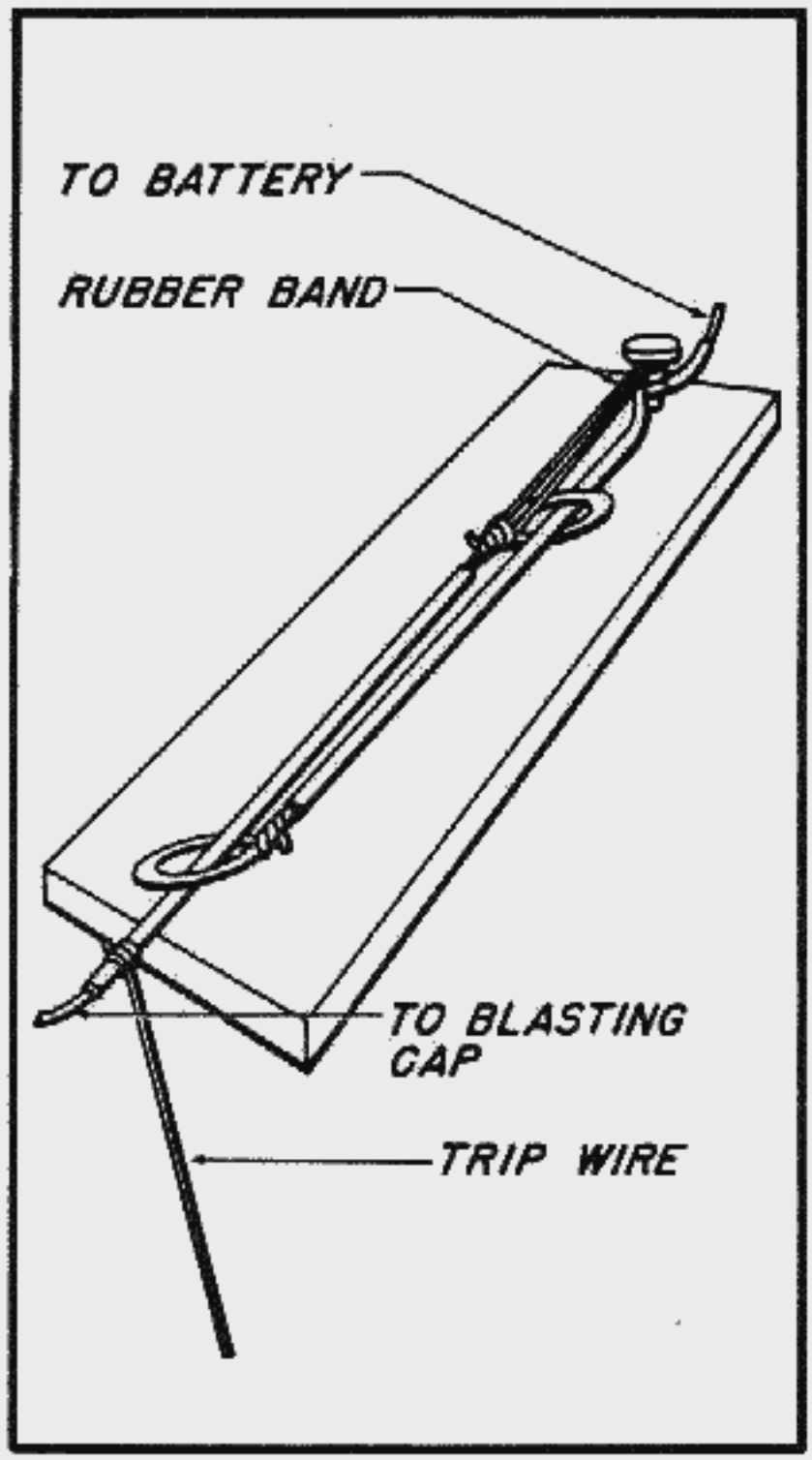


Fig. 15 — Electric Pull-Slide Switch

to the end of a stick, which can be about 10 or 12 inches long. To the same end of the stick, tie down the end of the wire which passes through the loop to which the rubber band is attached. An inch or more of this wire should extend beyond the end of the stick and the two loops should now be 2 or 3 inches apart. See Figure 15.

4. Attach the trip wire or string near the straight end of the hookup wire to which the rubber band is fastened. A pull on the trip wire should now stretch the rubber band and bring the two bare loops into contact.

5. Test the circuit and operation of the device.

To use the device, fasten the stick securely to a fixed object near the charge to be fired. Locate the trip wire in such a manner that the intended target will trip over it, or run it to a concealed position where it can be controlled by the operator. Check the circuit to be sure it is open before making final connections to battery and blasting cap.

Acid and Rubber Chemical Delay

This is a simple nonelectric delay device, but it will not work reliably at temperatures below 40° Fahrenheit. The time delay will depend upon temperature and the thickness of the rubber barrier used. At 70° a rubber contraceptive will provide a delay of 15 to 20 minutes. A rubber balloon, being thicker, will provide a longer delay.

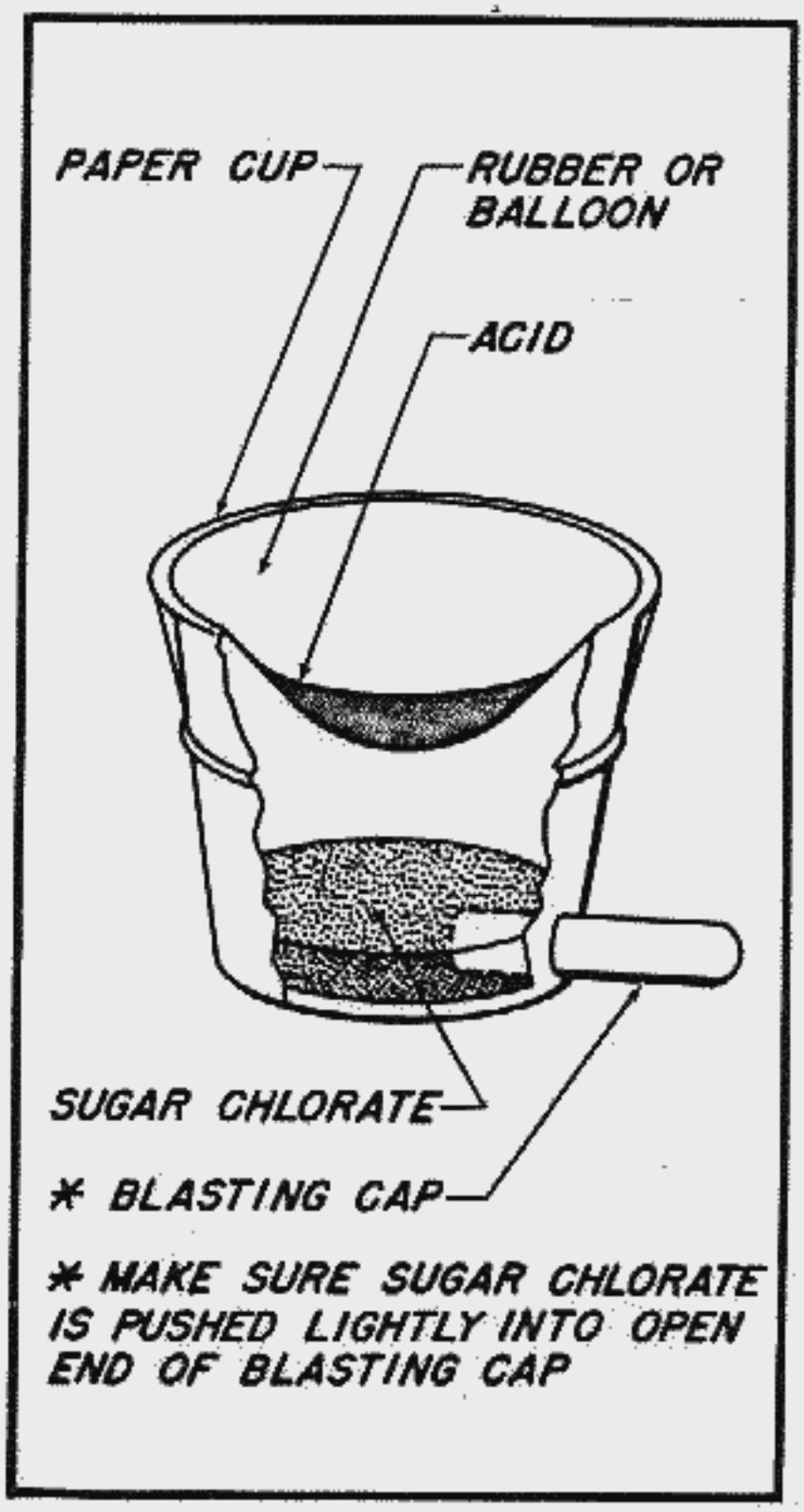

PAPER CUP
RUBBER OR BALLOON
ACID
SUGAR CHLORATE
* BLASTING CAP
* MAKE SURE SUGAR CHLORATE IS PUSHED LIGHTLY INTO OPEN END OF BLASTING CAP

Fig. 16 — Acid and Rubber Chemical Delay

MATERIALS: Small container such as a paper cup or tin can, rubber contraceptive or toy balloon, sugar-chlorate mixture (see section on incendiaries), CONCENTRATED sulfuric or nitric acid, nonelectric blasting cap.

PREPARATION:

1. Put two spoonsful of sugar-chlorate mix into the container.

2. Carefully check the rubber membrane to be used to be sure it has no tiny pinholes through which the acid could leak. Fasten the membrane over the top of the container completely and securely, but leaving a pocket in the membrane deep enough to hold a spoonful or so of liquid. See Figure 16.

To activate the delay, first fasten the container securely in an upright position. Make a hole in the side of the container near the bottom and insert the open end of a nonelectric blasting cap. Be sure that some of the sugar-chlorate mix gets into the open end of the cap. The business end of the blasting cap can be inserted directly into the explosive charge or connected to the charge with primacord. To start the delay, carefully place a spoonful of concentrated acid in the pocket of the membrane -- preferably using an eyedropper. When the acid eats through the membrane, the resulting flame will be sufficient to fire the blasting cap.

If necessary, a paper barrier may be used in place of rubber, but in any case the material should be tested before using.

Chemical Instantaneous Initiator

A simple nonelectrical initiating device which can be activated by pressure or by a trip wire.

MATERIALS: Eyedropper or other small glass tube or vial, rubber contraceptive or toy balloon, sealing wax, sugar-chlorate mixture (see section on incendiaries), CONCENTRATED sulfuric or nitric acid, nonelectric blasting cap.

PREPARATION:

1. Seal the narrow end of an eyedropper in an open flame or with sealing wax and remove the bulb from the other end.

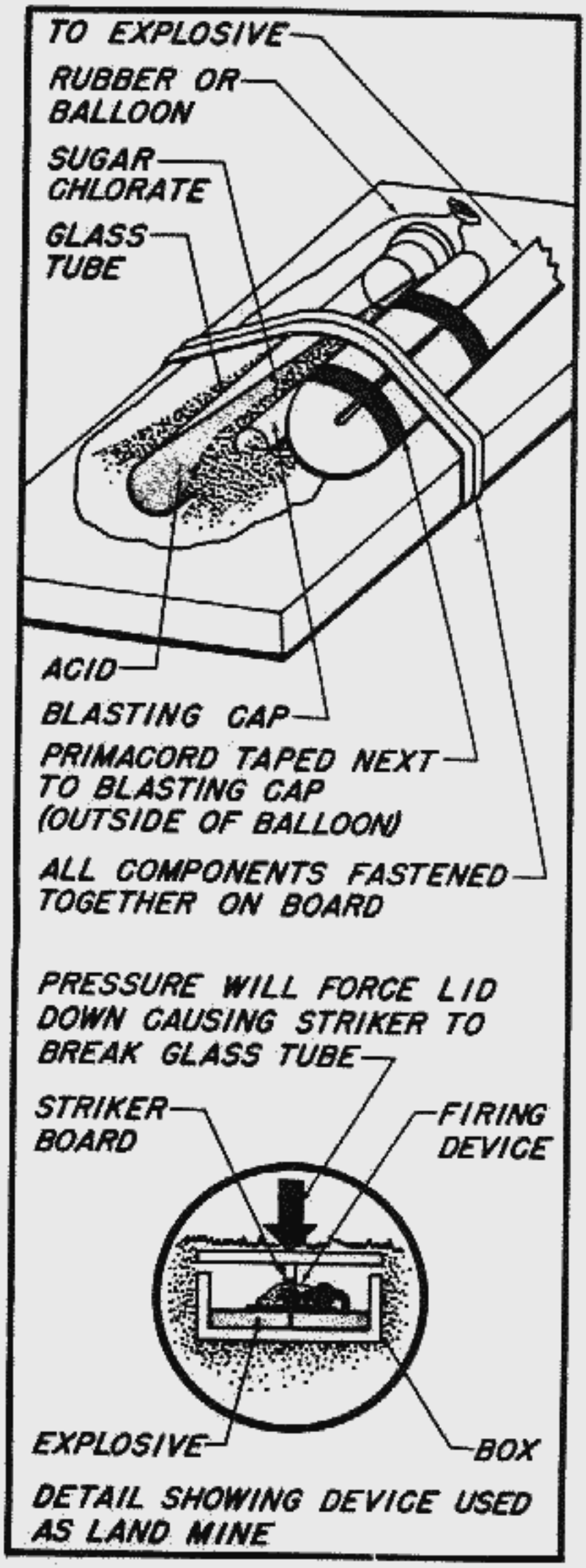


Fig. 17 — Chemical Instantaneous Initiator

2. Carefully fill the dropper at least half full of concentrated acid and seal the open end with wax. Let cool, then rinse and dry thoroughly to insure that no acid is on the outer surface.

3. Place the acid ampule into a rubber contraceptive or toy balloon, along with a few spoonsful of sugar-chlorate mixture and one nonelectric blasting cap. Then tie the opening of the rubber container tightly. See Figure 17.

A pressure method of crushing the ampule and firing the device is illustrated in Figure 17. Such a setup should be prior tested with an empty ampule to be sure pressure of the treadle alone will not crush the glass container.

A pull or trip wire system can be arranged by attaching the trip wire to a weight suspended or lodged above the ampule in such a manner that the weight will fall if the wire is cut or pulled.

Final positioning of this device is a bit tricky and requires care.

First, a length of primacord must be securely attached to the explosive end of the blasting cap from outside the rubber container so that only the thickness of the rubber separates the two.

Secondly, be sure the acid ampule is surrounded by the sugar-chlorate mixture and that the open end of the blasting cap is lying in a quantity of the mixture.

Fuse Lighter Nonelectric Pull

This device employs a modified mechanical fuse lighter to construct a booby trap or a firing device which can be controlled by the operator.

MATERIALS: M-2 fuse lighter, trip wire or string, nonelectric blasting cap.

PREPARATION:

1. Remove and discard the pull ring of the fuse lighter and ease the cotter pin partially out until only the last 1/8 inch or so of the tips protrude.

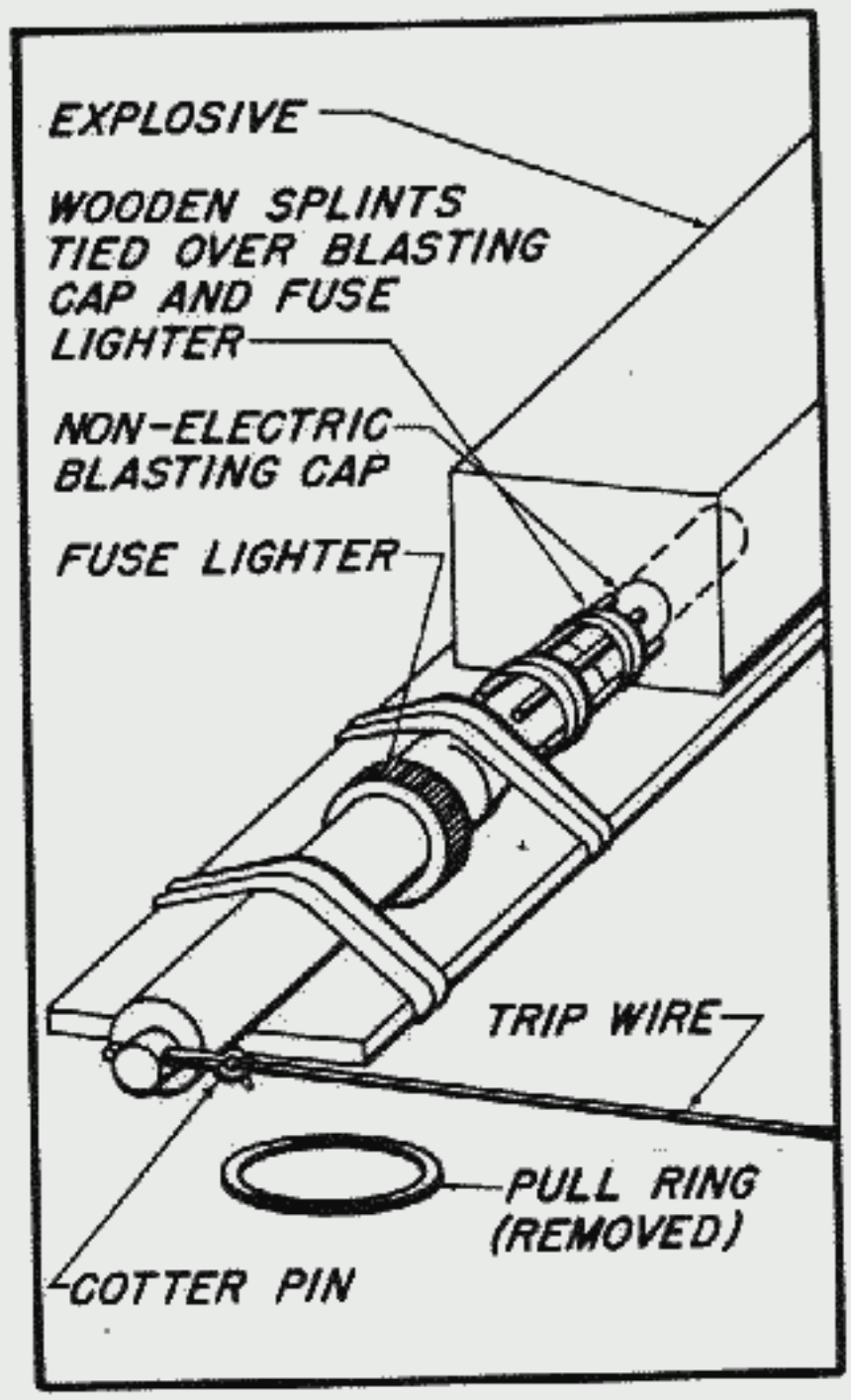


Fig. 18 — Fuse Lighter Nonelectric Pull

2. Taper the open end of the blasting cap slightly with crimper or pliers and insert it firmly into the open end of the fuse lighter.

3. Fasten the cap securely in place with wood splints and string or tape as illustrated in Figure 18.

To use this device, the blasting cap may be inserted directly into the explosive or it may be connected to the explosive with primacord. In either case the firing device should be securely attached to a solid object. Run the trip wire from a fixed location to the cotter pin, leaving some slack in the line. A pull on the trip wire will remove the cotter pin, initiating the charge.

PRECAUTION: Since there is no safety pin in this device, beyond the cotter pin, extra care must be used to prevent accidental operation.

Fuse Lighter Nonelectric Pressure

This device employs a modified fuse lighter to initiate a booby trap when the target applies pressure -- such as in an antivehicle mine or a derailment system.

MATERIALS: Scrap wood and nails, M-2 fuse lighter, nonelectric blasting cap.

PREPARATION:

1. Follow steps 1, 2, and 3 and same precautions as in preceding technique.

2. Fashion a pressure board which, when moved downward, will pull the cotter pin from the fuse lighter. See Figure 19.

The blasting cap may be inserted directly into the explosive or a primacord connection can be used.

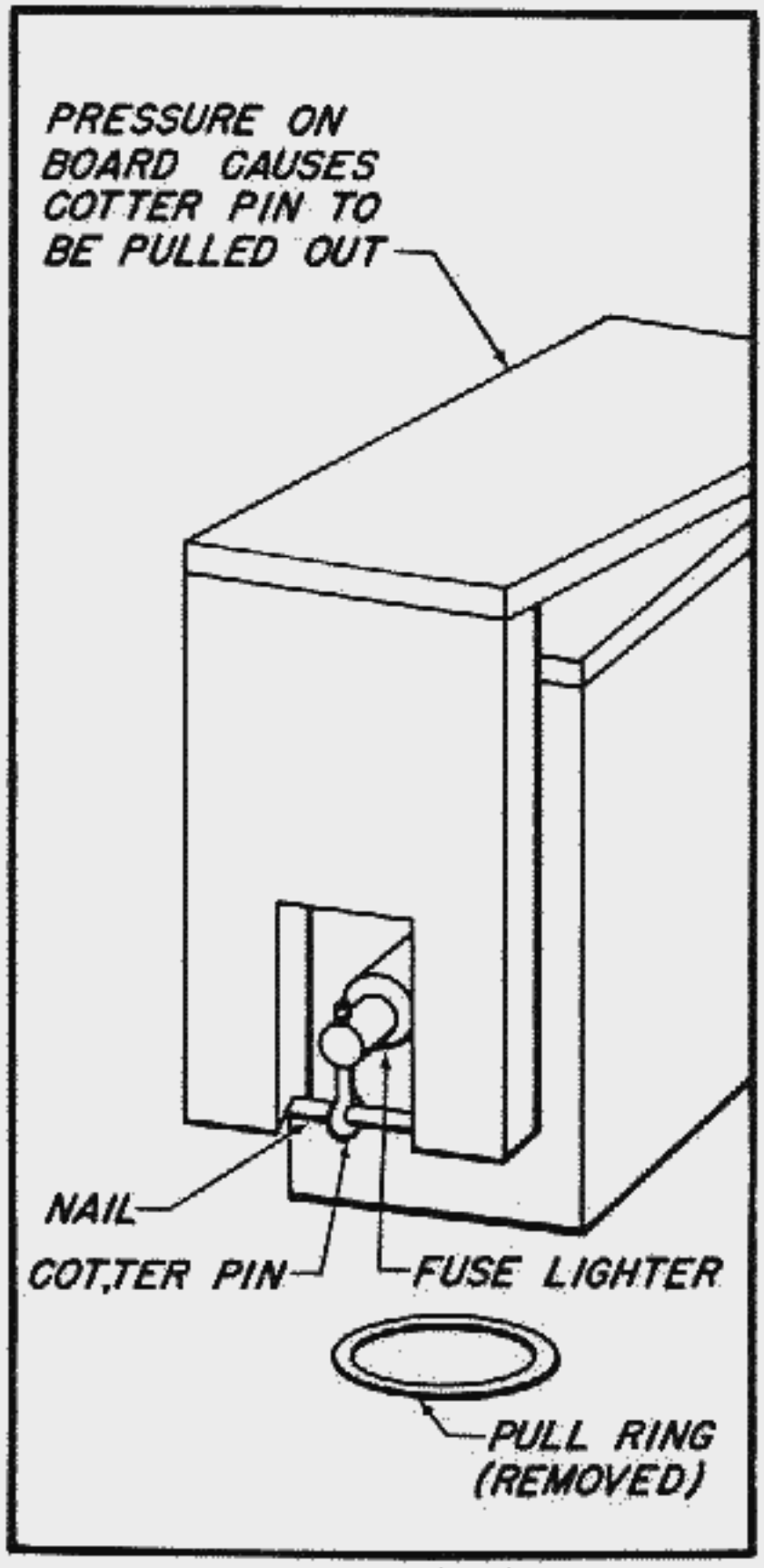


Fig. 19 — Fuse Lighter Nonelectric Pressure

IMPROVISED DETONATORS

General

One of the more difficult things to improvise in the field is a substitute for a blasting cap. This section will discuss two feasible techniques: one, the fabrication of a detonator by using a rifle, and two, cannibalizing the detonator from a fragmentation grenade.

Improvised Rifle Detonator

This technique provides a method of initiating primacord -- and thus any explosive charge -- if a regular blasting cap is not available. The device may be rigged as a booby trap with trip wire or it can be fired remotely by the operator. Since the technique does require the destruction of a usable rifle it likely would be used only when there is no other alternative. In addition, care should be taken in all phases of the preparation, because when the weapon is fired it will break into many fragments which would severely injure anyone holding the weapon or close to it.

MATERIALS: Expendable rifle, cartridge to fit rifle, primacord, trip wire or pull cord, wire or twine for lashing.

PREPARATION:

1. Check the rifle to be sure the safety and firing mechanism operate normally.

2. Remove the bullet from a live cartridge by gently loosening and pulling with pliers. Empty the powder from the cartridge and dispose of it by burning or save it in a moisture tight container for other uses.

3. Slit open about 1 yard of primacord with a sharp knife and collect the powder on a piece of clean paper or in some clean container. (NOTE: The explosive used in primacord usually is PETN. Other explosives sometimes used in detonating cord are Tetryl, RDX, and TNT. In this technique Tetryl will work as well as PETN. The others may not.)

4. Fill the empty cartridge case with the powder obtained from the primacord, packing it tightly with a pencil or stick. Do not pound or hammer on the stick. Leave the neck of the cartridge case empty.

5. Cut a length of primacord 1 yard longer than the barrel of the rifle. Insert one end into the empty neck of the cartridge. Hold the primacord firmly against the powder in the cartridge and carefully crimp the cartridge case neck around the primacord with pliers. Care must he taken in this step to insure that the primacord is held securely in the cartridge case, but that the neck of the cartridge is not so badly distorted by the pliers that it will not slip easily into the chamber of the weapon.

6. Check the fit of the cartridge by feeding the loose end of primacord down the weapon's barrel from the breech end and out the muzzle. By gently pulling the primacord through the barrel and guiding the cartridge into the chamber, determine whether the cartridge fits easily and whether the action of the rifle will close fully over it. Do not force the cartridge or it will be difficult to remove after this check. If it does not fit properly, remove it and adjust the crimp with pliers until the proper fit is obtained.

To use this device, firmly lash the unloaded rifle to a fixed object such as a stake or tree. See Figure 20. Tie a long pull cord or trip wire to the trigger and test the empty weapon once or twice to see that the trigger moves freely when pulled and that the firing pin snaps forward.

When the installation has been completed and checked, then load the primacord and detonator into the rifle as before -- leaving the action of the rifle open.

Connect the charge to be fired by tying the primacord leading from the charge to the end of the primacord extending from the muzzle of the rifle.

Before closing the action of the rifle, position the trip wire or pull cord, making sure there is enough slack to avoid tension on the trigger.

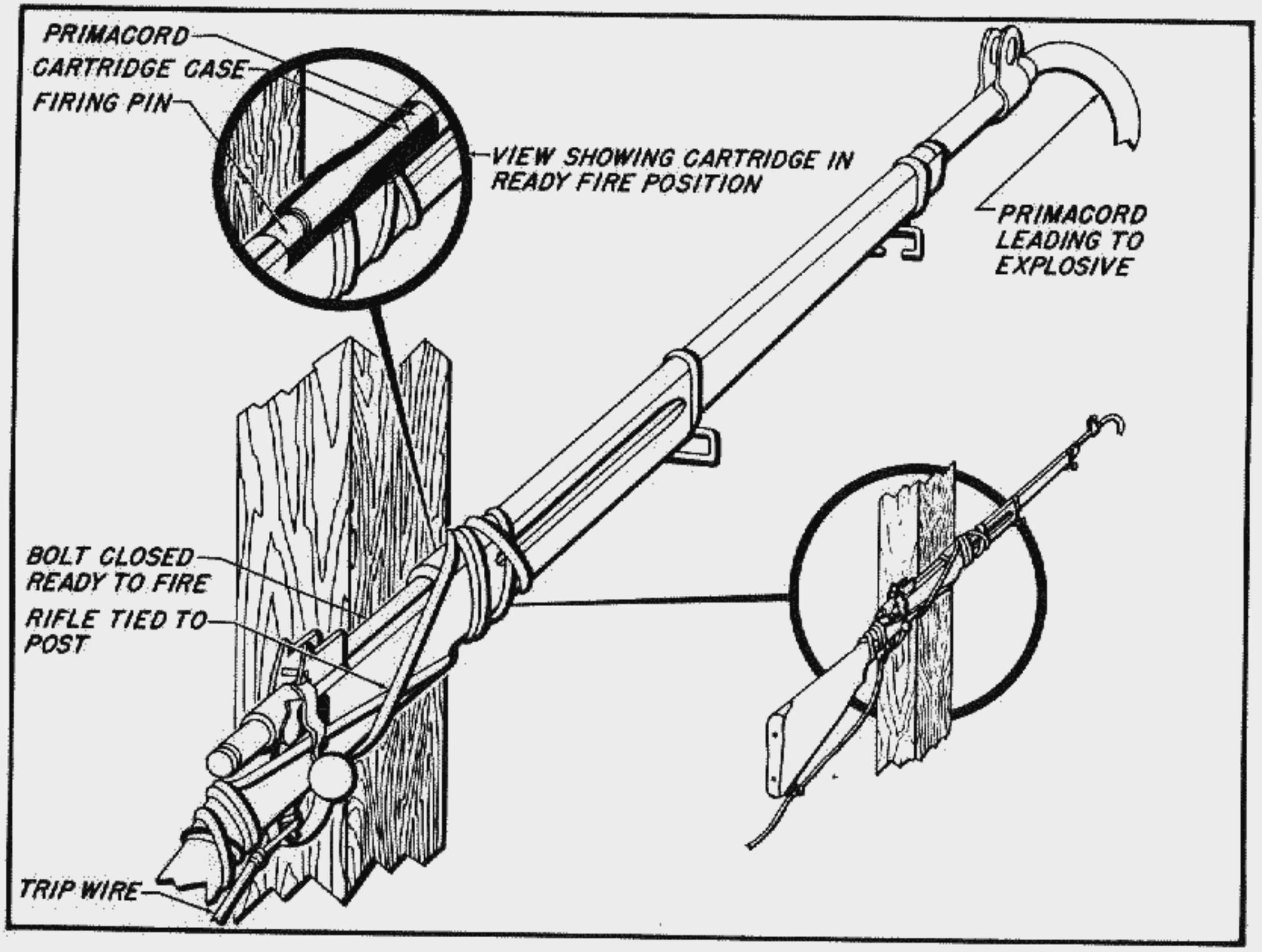


Fig. 20 — Improvised Rifle Detonator

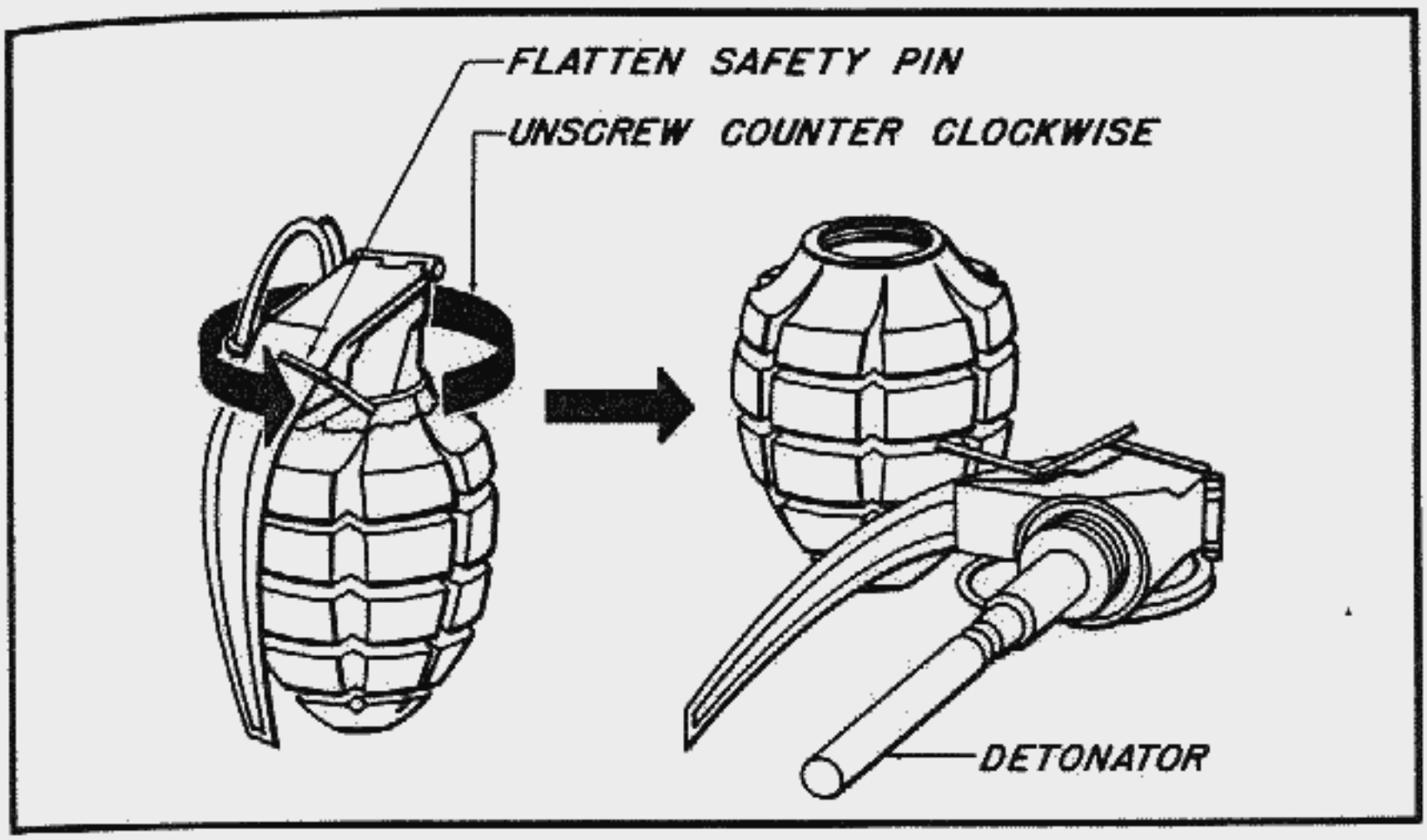


Fig. 21 — Removing Grenade Fuse

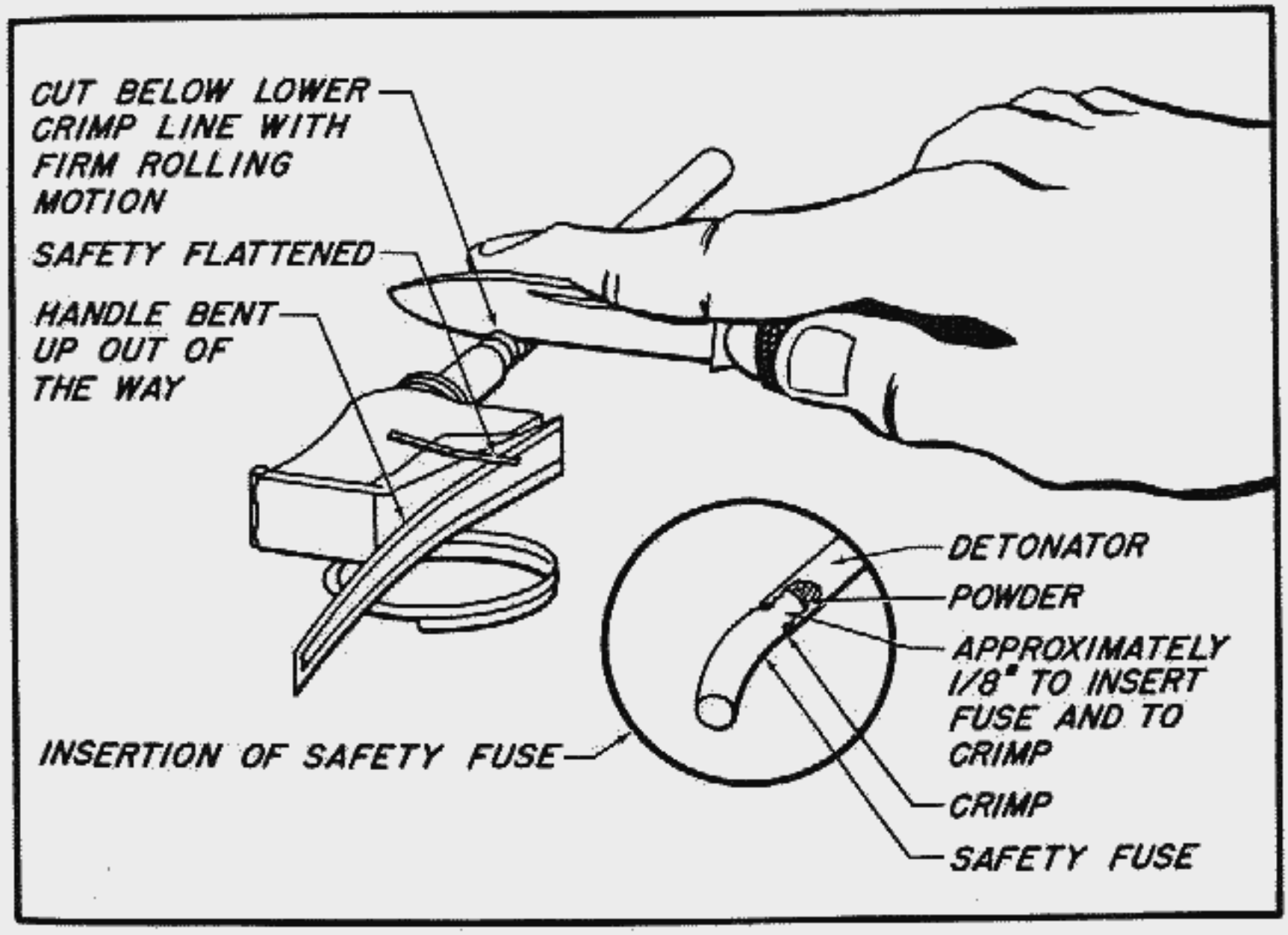


Fig. 22 — Removing Grenade Detonator

Now close the action of the rifle, release the safety, and retire to a safe position at least 50 yards away, being sure not to trip over the trip wire or pull cord. If the pull cord is used, take up any slack in the line and then pull firmly to fire the weapon and detonate the charge.

Frag Grenade Detonator

Nonelectric blasting caps can be obtained from fragmentation or other bursting grenades for use in detonating explosives. The detonator in a frag grenade is strong enough to set off pressed TNT, plastic explosives, and primacord. Detonators used in some countries are less powerful, but in all cases they will initiate primacord, which in turn can be used to set off any explosive. With weak detonators and no primacord, it may be possible to use two or three together to detonate less sensitive explosives such as plastics.

MATERIALS: Fragmentation grenade.

PREPARATION:

1. Spread and flatten out the points of the safety cotter pin to insure it will not be accidentally pulled out. Bend the fuse lever back out of the way.

2. The fuse assembly can now be safely removed from the body of the grenade with pliers. See Figure 21.

3. With a sharp knife cut around the detonator just below the lowest or second crimp mark where it is attached to the fuse assembly. This is most easily done by holding the knife firmly on the metal and slowly rolling the detonator-fuse assembly on a flat surface. See Figure 22. The soft metal of the detonator case cuts easily, allowing the detonator to be pulled off the nipple of the fuse assembly.

4. Inspection will reveal a shallow depression in the open end of the detonator. This depression, about 1/8 inch deep, is sufficient to permit the crimping of the detonator to time fuse if care is taken. See Figure 22. In lieu of crimping, the detonator can be taped to the fuse.

STEEL CUTTING TECHNIQUES

General

Many of the more critical target structures in sabotage operations are made of steel. Plastic explosives are the best for steel cutting. They are easier to place and permit the use of a simple rule of thumb for determining the amount of explosive needed rather than working out a complicated mathematical formula. Also, if the proper techniques are used much less explosive is required to do the job than demolitions formulas call for.

Rule of Thumb for Structural Steel

A strip of plastic explosive as thick as the steel to be cut, and as wide as it is thick, will cut through mild steel. This "ribbon" charge should be prepared in such a manner that it can be quickly placed and held in good contact against the steel where the cut is desired. See Figure 23.

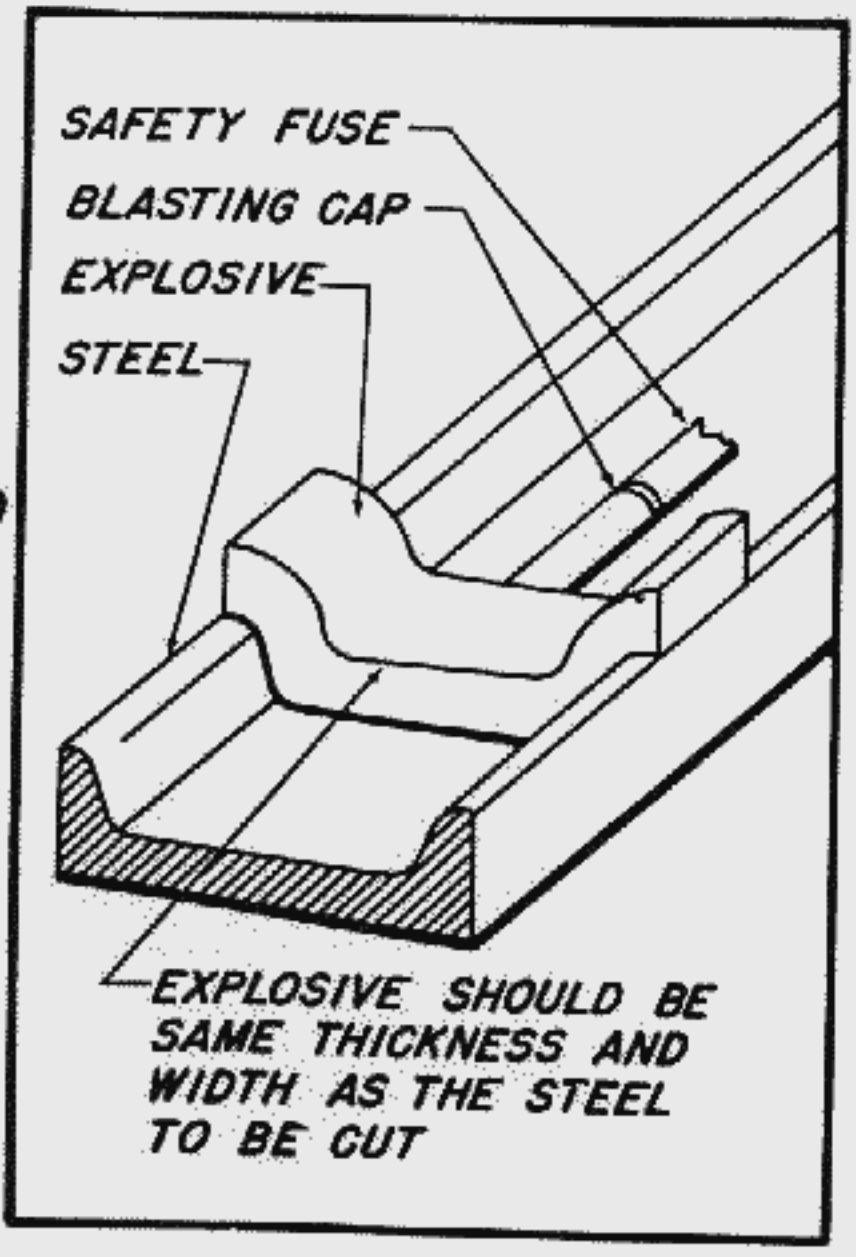


Fig. 23 — Ribbon Charge for Steel

When the exact dimensions of the target steel are known, a charge may be tailored in advance to fit perfectly. See Figure 24. If the target measurements can only be estimated, a more flexible charge can be prepared as shown in Figure 25.

MATERIALS: Wood scraps or tin strips, rags, string, blasting cap, plastic explosive.

PREPARATION:

1. Slice the explosive into strips of the same thickness and width as the thickness of the steel to be cut. This should be done with a sharp knife to preserve the density of the packaged explosive.

2. Wrap this explosive ribbon in one layer of cloth and tie it to a scrap of wood of the

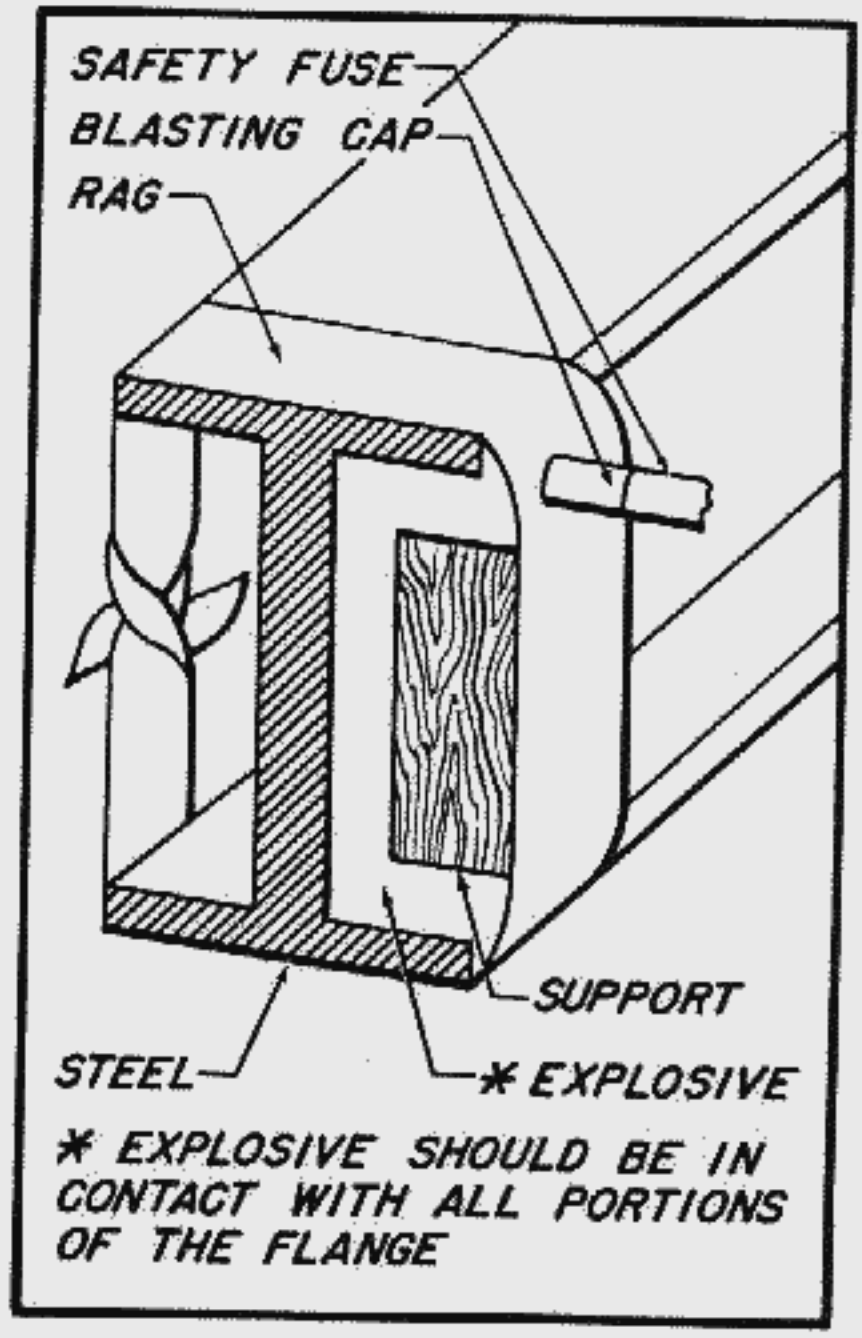


Fig. 24 — Tailored Ribbon Charge

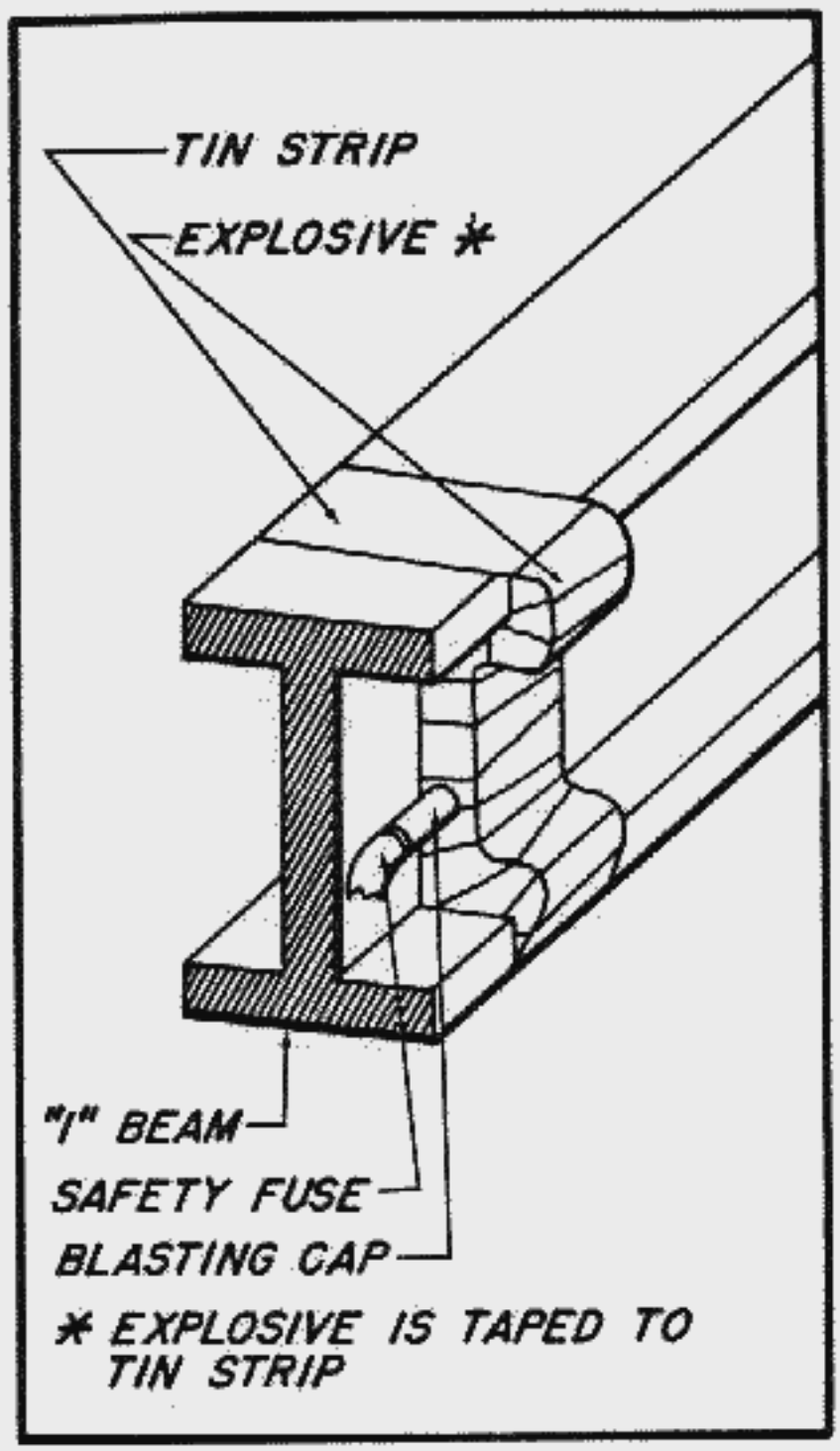


Fig. 25 — Flexible Ribbon Charge

proper size to make a package that will fit snugly against the target. See Figure 24.

3. If the dimensions of the steel to be cut are not known, fasten a strip of explosive thicker and longer than the estimated measurements of the target to a strip of tin. This provides a flexible charge which can be shaped to the target. The charge should be wrapped in cloth to hold the explosive together and protect the hands from sharp edges of the tin. The tin strip should be longer than the explosive, allowing 6 inches at each end of the charge for wrap-around to hold the charge in place. See Figure 25.

4. Prepare a hole for the blasting cap in one end of the charge to simplify priming at the target.

In placing the charge, fasten it securely on the target, being sure the explosive is in good contact with steel at all points. Insert the blasting cap and compress the explosive firmly around it.

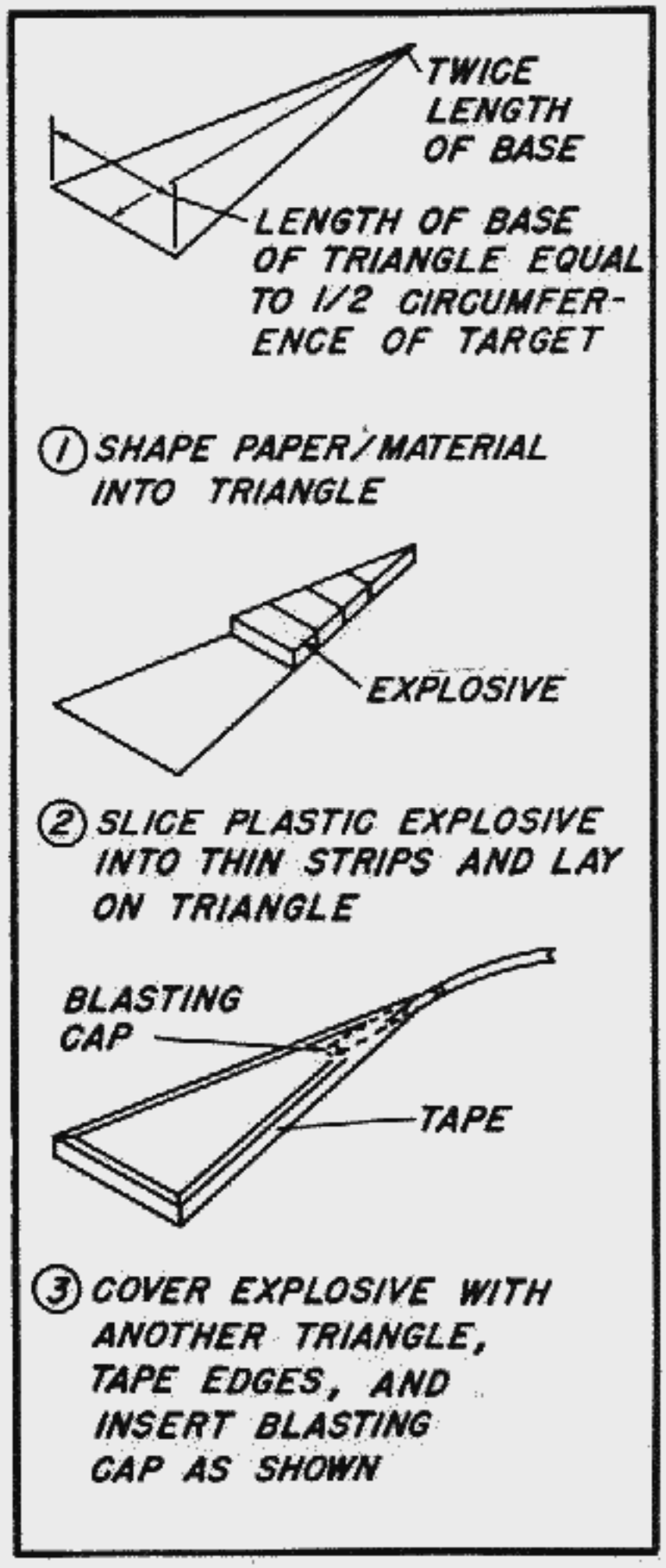

TWICE LENGTH OF BASE
LENGTH OF BASE OF TRIANGLE EQUAL TO 1/2 CIRCUMFERENCE OF TARGET
(1) SHAPE PAPER/MATERIAL INTO TRIANGLE
EXPLOSIVE
(2) SLICE PLASTIC EXPLOSIVE INTO THIN STRIPS AND LAY ON TRIANGLE
BLASTING CAP
TAPE
(3) COVER EXPLOSIVE WITH ANOTHER TRIANGLE, TAPE EDGES, AND INSERT BLASTING CAP AS SHOWN

Fig. 26 — Saddle Charge

Cutting Steel Bars and Shafts

A triangular or "saddle" charge has been found to be highly effective in cutting bars and shafts. Its chief advantages are that it is easily placed and the cutting action is positive.

MATERIALS: Paper or cloth, tape, blasting cap, plastic explosive.

PREPARATION:

1. Prepare a paper or cloth pattern in the form of a triangle. The base of the triangle should measure 1/2 the circumference of the bar or shaft to be cut and the height of the triangle should be twice the measurement of the base.

2. Slice layers of plastic explosive 1/2 to 3/4 inch thick with a sharp knife. Make the slices as even in thickness as possible, being careful not to destroy the density of the explosive.

3. Place these layers of explosive over the triangular pattern until it is fully covered. Push the slices firmly together, leaving no air gaps in between, and trim off any edges extending beyond the pattern.

4. Cover the triangular charge with another piece of paper or cloth, wrap firmly and bind with tape to prevent the charge from falling apart. See Figure 26.

The triangular charge should be snugly wrapped, tied, or taped to the target bar or shaft, with the base of the triangle along the line where the cut is desired. The blasting cap should be inserted at the apex of the triangle and the plastic explosive pressed tightly around it.

STANDARD CHARGE

The standard charge provides a basic, versatile demolitions tool which can be made up in advance and utilized in many situations, especially when specific knowledge of the target is not available.

MATERIALS: Tape, primacord, plastic explosive.

PREPARATION:

1. Cut two pieces of primacord about a yard long. Onto each tie a triple roll or girth hitch knot with short pieces of primacord. The knots should be tight enough not to come untied, but they should slide easily along the main lines.

2. Split a half block of plastic explosive lengthwise and lay it open. Place the primacord lines and the two sliding knots between the two halves and adjust the knots so that one is just inside each end of the explosive. See Figure 27.

3. Close the two halves together over the primacord lines and knots. Tape or otherwise wrap and bind the charge tightly to insure close contact of explosive around the knots. Also tape the ends of the block so the knots will not pull out.

When completed, the charge can be slid along the primacord main line in either direction to permit adjustment on the target. Additional charges can be linked on by tying primacord ends together. Or, the single charge can be cut in two if smaller charges are desired and each will still have its own primacord leads and priming knot. If this is done, a simple knot should be tied in the ends of the primacord to keep the charge from sliding off.

Figure 28 suggests targets and placement of the standard charge.

NOTE: If primacord is in short supply, a single strand of primacord with two knots tied on it may be used in place of the dual system described and illustrated.

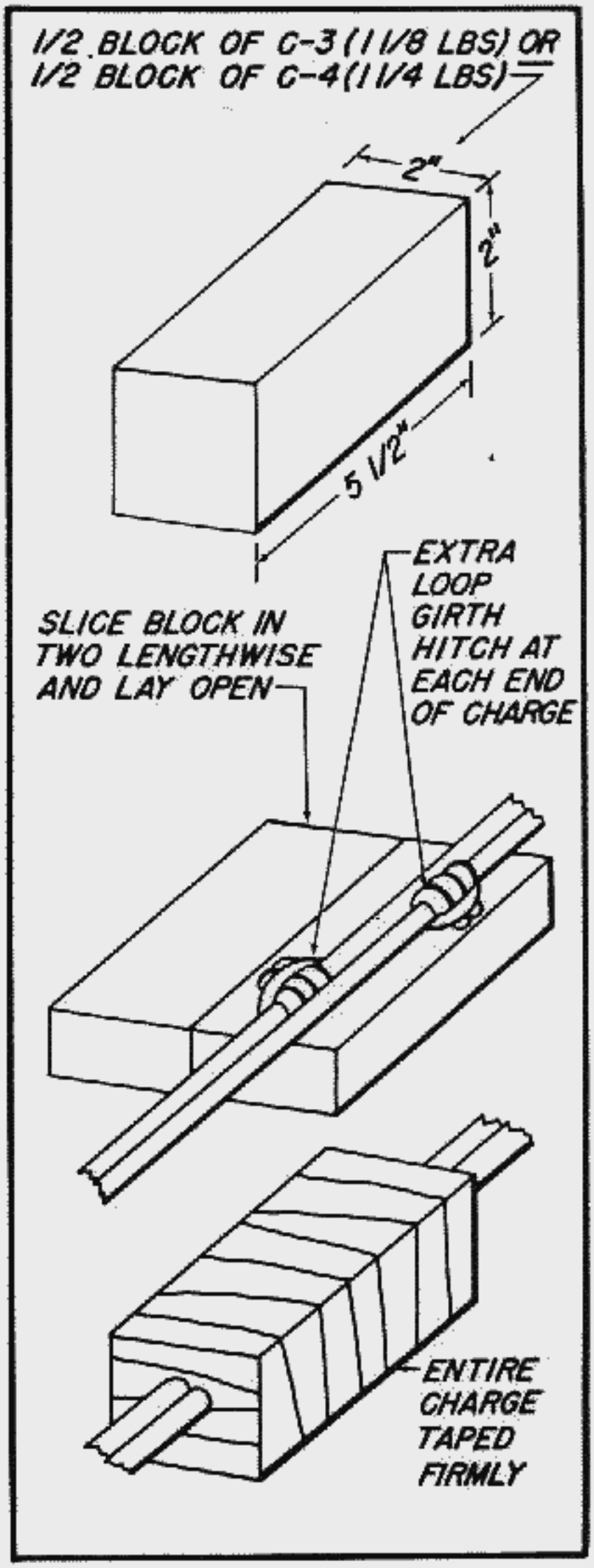

1/2 BLOCK OF C-3 (1 1/8 LBS) OR
1/2 BLOCK OF C-4 (1 1/4 LBS)
2"
2"
5 1/2"
SLICE BLOCK IN TWO LENGTHWISE AND LAY OPEN
EXTRA LOOP GIRTH HITCH AT EACH END OF CHARGE
ENTIRE CHARGE TAPED FIRMLY

Fig. 27 — Standard Charge

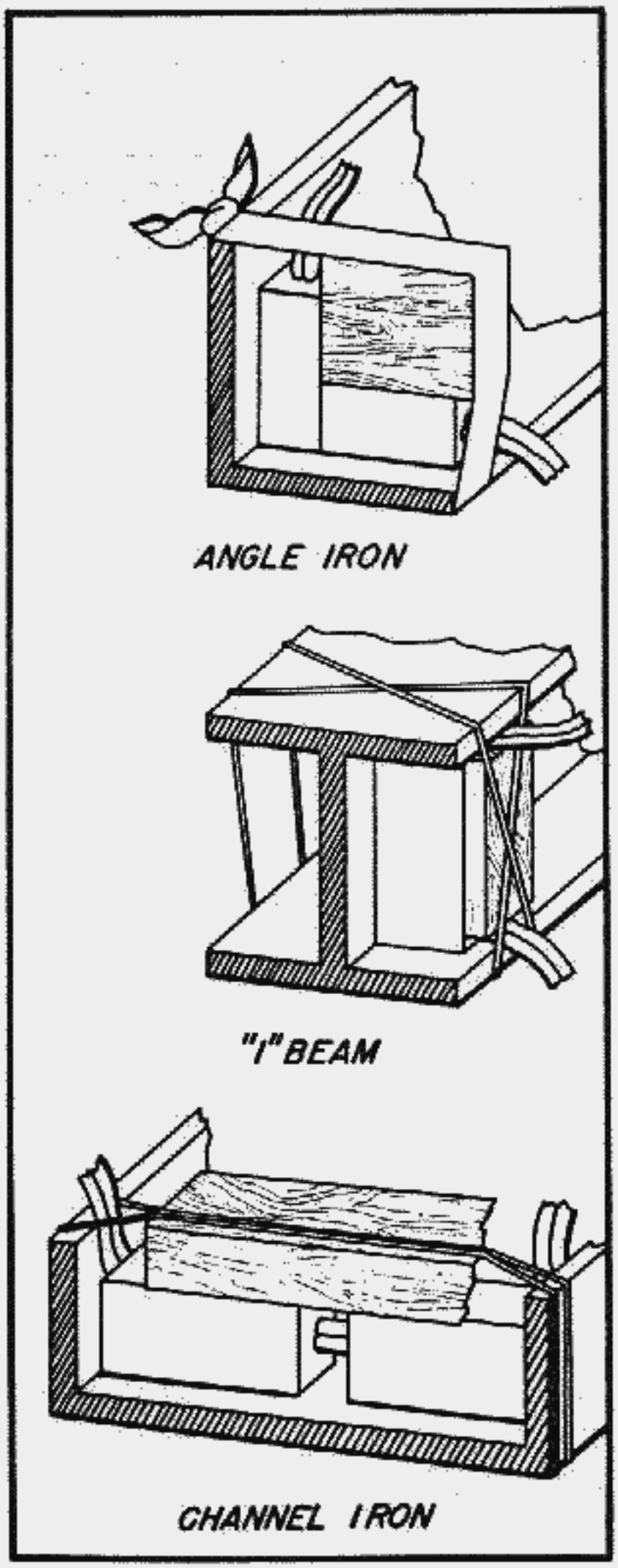


Fig. 28 — Standard Charge Placement

DERAILMENT TECHNIQUES

General

A primary resistance activity is damaging or destroying locomotives by derailment. To insure the derailment of a modern locomotive it is necessary to remove a length of rail equal to the length of the fixed wheel base of the locomotive. For practical purposes, removal of 20 feet of rail on one side of the track will result in the derailment of any locomotive.

The most effective place to make the cut is on the outside rail on a curve. Where two or more tracks parallel, derailment should be made in such a manner that a train wrecked on the inside track when rounding a curve will tear up and obstruct all the tracks.

The firing device used should be placed at least 5 feet ahead of the charges in the direction from which the train is expected, since the charges should detonate just ahead of the locomotive, not under it. If the direction of the train's approach is unknown, a firing device should be placed at each end of the string of charges.

This section describes two derailment techniques: one, a hasty method and, two, a concealed cratering system.

Hasty Derailment Method

When minimum time at the target is a primary consideration, the hasty method is an effective, quick way of taking out 20 feet of railroad track. The whole system can be prepared in advance and placed on target in a few seconds.

MATERIALS: Cord, string or rags, tape, primacord, plastic explosive, blasting caps, firing device.

PREPARATION:

1. Cut two lines of primacord at least 23 feet long and tie 8 to 10 triple roll or girth hitch knots at intervals of about 18 inches on each of them (see the previous section on the standard charge for instructions on tying the knots). The exact number of knots and the spacing will depend on the spacing of the crossties on the railroad track to be attacked. Be sure the knots are snug but loose enough to slide so adjustments in spacing of the charges can be made on the target.

2. Mold a half block of plastic explosive (minimum of 1 pound) around each pair of knots as described in the previous section on the standard charge and wrap or tape each

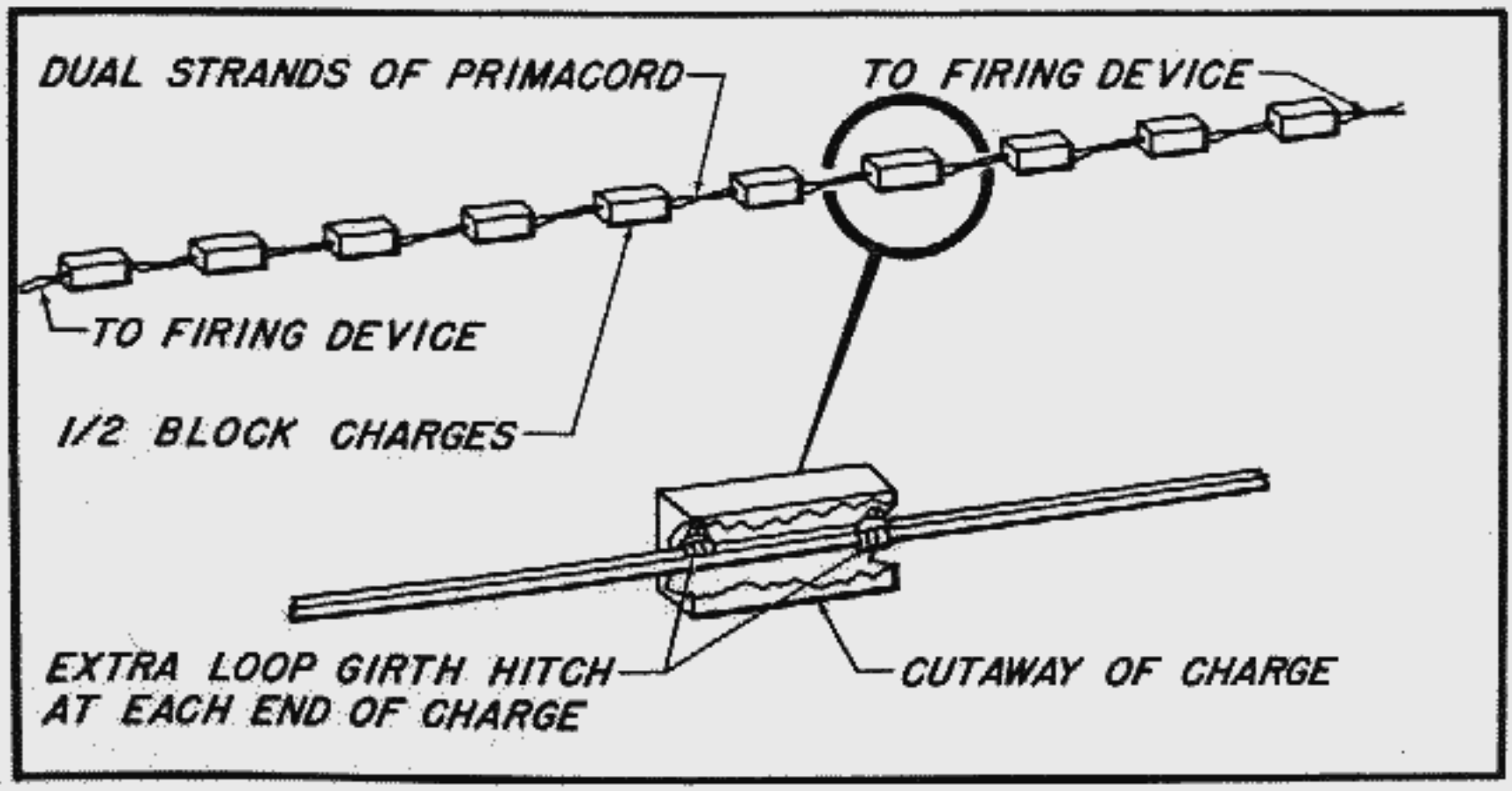

DUAL STRANDS OF PRIMACORD
TO FIRING DEVICE
TO FIRING DEVICE
1/2 BLOCK CHARGES
EXTRA LOOP GIRTH HITCH AT EACH END OF CHARGE
CUTAWAY OF CHARGE

Fig. 29 — Hasty Derailment Charge

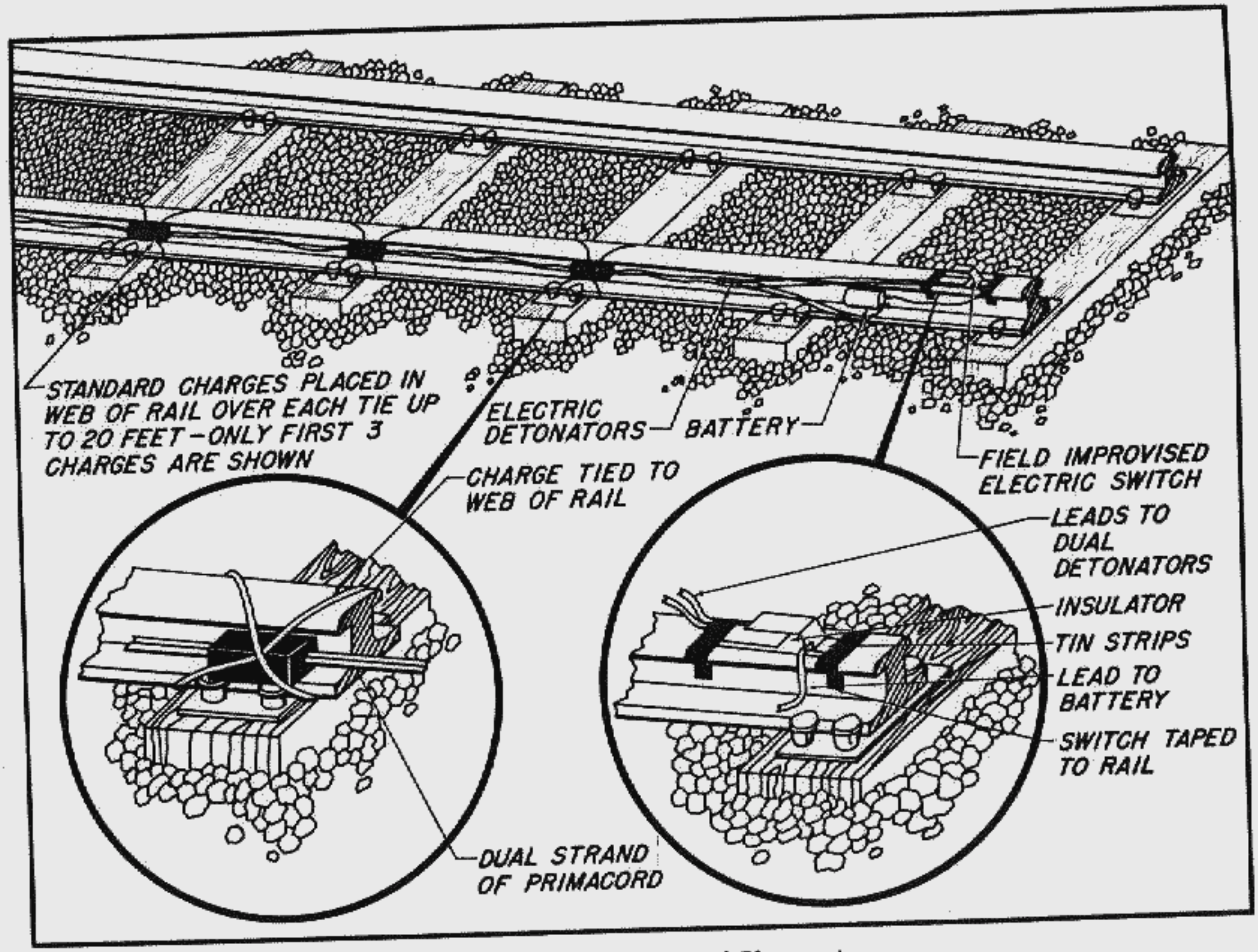

STANDARD CHARGES PLACED IN WEB OF RAIL OVER EACH TIE UP TO 20 FEET – ONLY FIRST 3 CHARGES ARE SHOWN
ELECTRIC DETONATORS
BATTERY
FIELD IMPROVISED ELECTRIC SWITCH
CHARGE TIED TO WEB OF RAIL
LEADS TO DUAL DETONATORS
INSULATOR
TIN STRIPS
LEAD TO BATTERY
SWITCH TAPED TO RAIL
DUAL STRAND OF PRIMACORD

Fig. 30 — Hasty Method Placement

charge securely so it can withstand rough handling while being transported and placed on the target. See Figure 29 for details of construction. (NOTE: A single main line can be used if primacord is scarce.)

3. At the target, lay the primacord line and the attached charges straight out along the section of rail to be cut. Be sure there are no kinks or sharp bends in the line. Attach a charge to the web of the rail directly over each tie in the 20 foot section. If strong magnets are available they can be fixed to the charges and provide a very quick means of attachment. Otherwise use cord, strips of cloth, wire, or tape. See Figure 30.

The special railroad torpedo firing device is the best initiator to use with this hasty method. It would be clamped to the top of the rail and attached to the chain of charges with a 5 or 6 foot length of primacord.

Among the alternative methods of initiation which could be prepared in advance and used in this technique is the electric pressure switch improvised out of metal straps which was shown in Figure 7. Figure 30 illustrates this application. BE SURE, however, that the metal straps are completely insulated from the rail by a sheet of rubber, wood, cardboard, or heavy paper.

Concealed Cratering System

If the operational situation permits extra time on the target and some noise, the concealed cratering technique for derailment is more sure-fire since it also tears up ties and roadbed. It also alleviates the danger of detection by track inspection prior to the passage of a train.

MATERIALS: Tape, primacord, plastic explosive, blasting caps, firing device.

PREPARATION:

1. Cut two main lines of primacord about 23 feet long or longer and 4 or 5 shorter pieces to serve as branch lines. (NOTE: A single main line can be used if primacord is scarce.)

2. Tie two sliding triple roll or girth hitch knots (see section on standard charge) to each of the branch lines.

3. For each branch line slice open a FULL BLOCK of plastic explosive lengthwise, and mold it around the middle of the branch line with a knot just inside each end of the block.

4. Cut the block of explosive crosswise into two equal lengths, being sure not to cut through the primacord in the center. Now fold the two portions of the block together (see Figure 31) and tape or tie securely. Tie or tape the free ends of the primacord together. This method of constructing the charge will permit much rougher handling in transporting it and placing it on the target than if a single strand of primacord with a single knot in the end is used.

5. To install this system at the target, scoop out ballast as necessary and bury one charge IN EVERY OTHER SPACE BETWEEN TIES directly under the rail to be removed. Attach the branch lines from the charges to the main primacord line and cover the whole system with ballast. See Figure 31.

A pressure firing device which can be concealed under the rail or a tie is best to use with the cratering system. Figure 19 illustrates such an improvised pressure device, utilizing a modified M-2 fuse lighter.

IMPROVISED CRATERING EXPLOSIVE

In general, improvised explosives are too complicated to prepare or too weak for steel cutting and most other sabotage tasks. However, if the problem is to get a quantity of lower velocity explosive for cratering or moving a large volume of earth or rock, a good simple one can be prepared from ammonium nitrate fertilizer.

This improvised explosive can be used for attacking bridge abutments, or causing a landslide to block a mountain pass, close a tunnel, derail a train, or similar purposes.

To prepare the explosive, simply mix about one gallon of fuel oil or motor oil to one bag (80-100 pounds) of fertilizer. The mixing can be done in the bag or in the bore hole prepared to receive the charge. Use about the same amount of the mixture in weight as would be required of dynamite.

Best results are obtained with ammonium nitrate fertilizer which has a 33 percent nitrogen content. For reliable detonation and maximum cratering effect the mixture should be in a confined space such as a bore hole and tamped with earth or otherwise covered and compressed. Also it is easily weakened by moisture and should not be used in a wet situation unless it is sealed in a watertight container.

Because this improvised explosive is extremely insensitive, a booster is required to initiate it. A half pound charge of any high explosive in the bottom of the hole will be sufficient to insure detonation.

While insensitive to shock, the mixture is a fire hazard and normal precautions against fire should be observed. If 50 pounds or more is being used in one charge, anyone within a few hundred yards is in danger of being struck by flying debris.

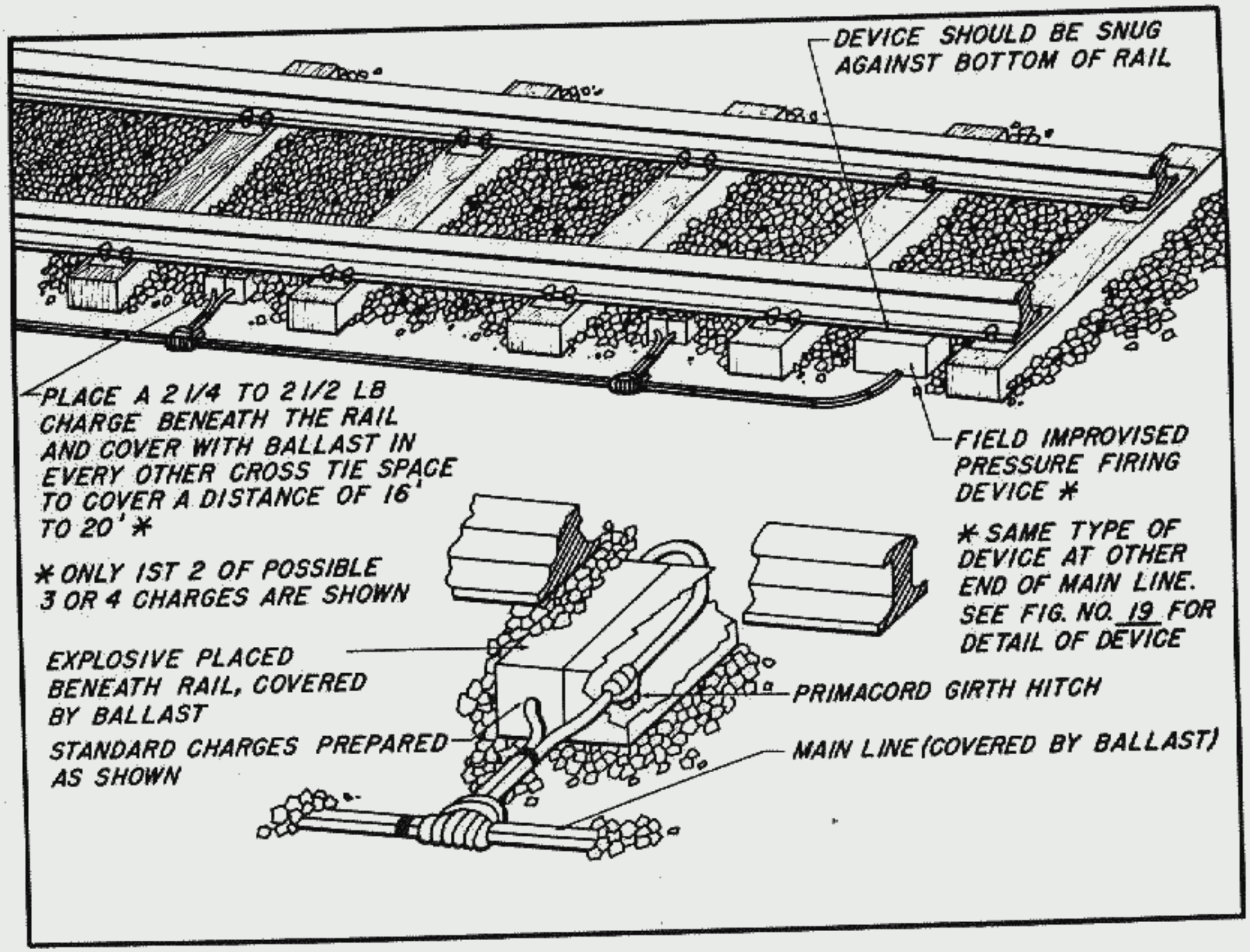

DEVICE SHOULD BE SNUG AGAINST BOTTOM OF RAIL
PLACE A 2 1/4 TO 2 1/2 LB CHARGE BENEATH THE RAIL AND COVER WITH BALLAST IN EVERY OTHER CROSS TIE SPACE TO COVER A DISTANCE OF 16' TO 20' *
* ONLY 1ST 2 OF POSSIBLE 3 OR 4 CHARGES ARE SHOWN
FIELD IMPROVISED PRESSURE FIRING DEVICE *
* SAME TYPE OF DEVICE AT OTHER END OF MAIN LINE. SEE FIG. NO. 19 FOR DETAIL OF DEVICE
EXPLOSIVE PLACED BENEATH RAIL, COVERED BY BALLAST
STANDARD CHARGES PREPARED AS SHOWN
PRIMACORD GIRTH HITCH
MAIN LINE (COVERED BY BALLAST)

Fig. 31 — Concealed Derailment System

CONE SHAPED CHARGES

General

Shock waves from a detonating block of explosive emerge in all directions, creating a generalized blast effect. It is possible, however, to shape an explosive charge in such a way that a portion of the shock waves will be focused and concentrated on a very small area, thereby creating a very powerful puncturing or drilling action.

A familiar military use of this principle is the 3.5 inch antitank rocket, or bazooka round. The explosive charge in the head of the rocket has a conical cavity in the forward end. When the charge is detonated against the side of a tank, the shock waves emerging from the conical cavity are focused on one spot where they will penetrate several inches of tough steel.

The cone shaped charge has excellent possibilities for sabotage especially for use against industrial machinery. The 3.5 rocket itself provides one of the very best shaped charges. A later section on this versatile weapon will describe and illustrate how the rocket head can be removed and used as a placed shaped charge.

Lacking a 3.5 round, an effective shaped charge can be fashioned around any cone shaped glass object. Following are directions on how to do it with a martini glass or a wine bottle with a dome shaped bottom.

Martini Glass Shaped Charge

MATERIALS: Martini or wine glass, beer can or other tubular container or cardboard from which to fashion one, sticks, tape or string, plastic explosive.

PREPARATION:

1. File a notch around the stem at the base of a martini or wine glass as shown in Figure 32. Rap the stem sharply against a solid object to break it off from the cone of the glass.

2. Place the glass upside down in any cylindrical container or cardboard tube fashioned to the diameter of the mouth of the glass. Unless the glass is wedged firmly in the container, tape it around the rim to hold it in place.

3. Pack plastic explosive behind the apex

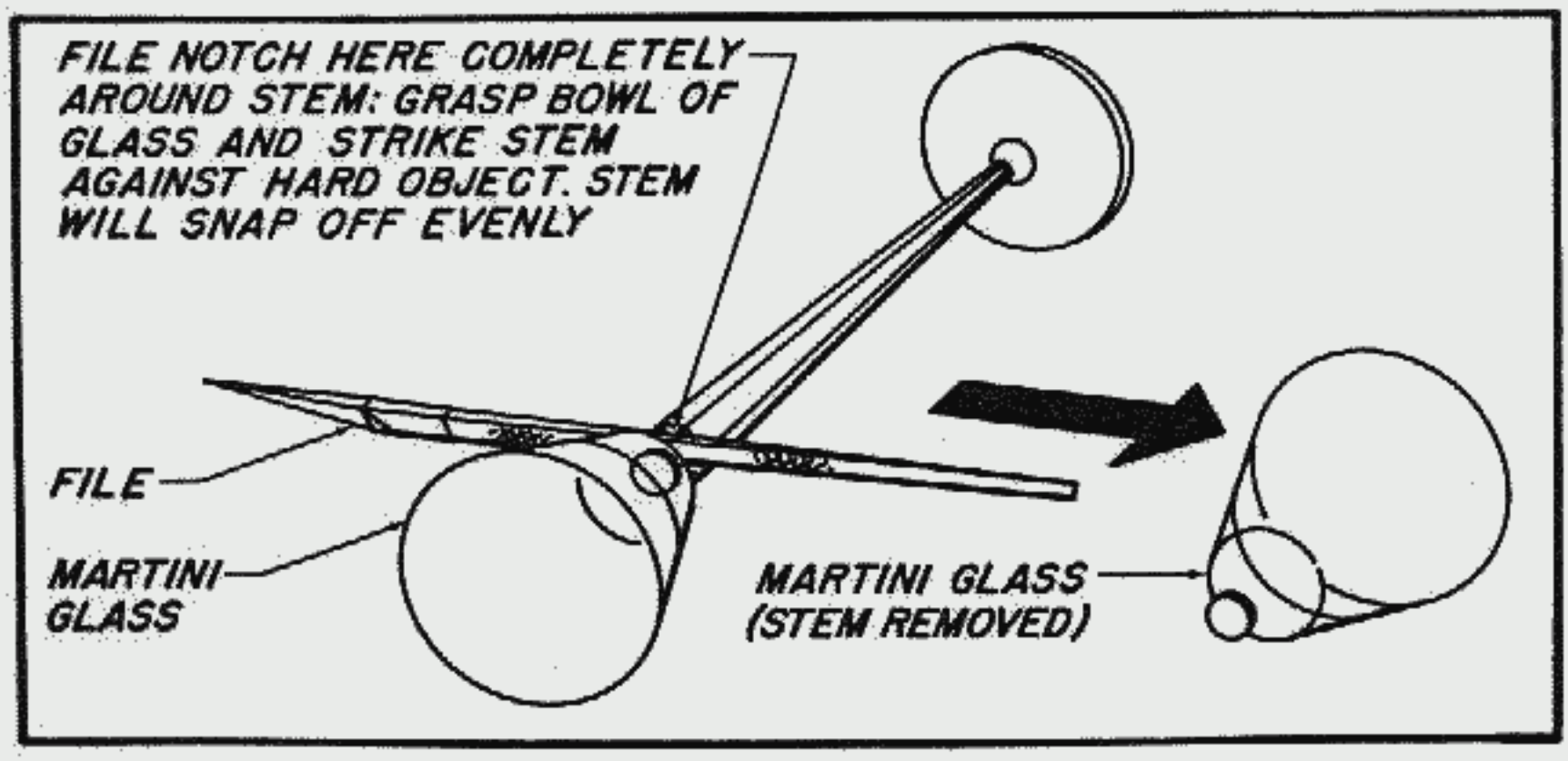

FILE NOTCH HERE COMPLETELY AROUND STEM: GRASP BOWL OF GLASS AND STRIKE STEM AGAINST HARD OBJECT. STEM WILL SNAP OFF EVENLY
FILE
MARTINI GLASS
MARTINI GLASS (STEM REMOVED)

Fig. 32 — Removing Glass Stem

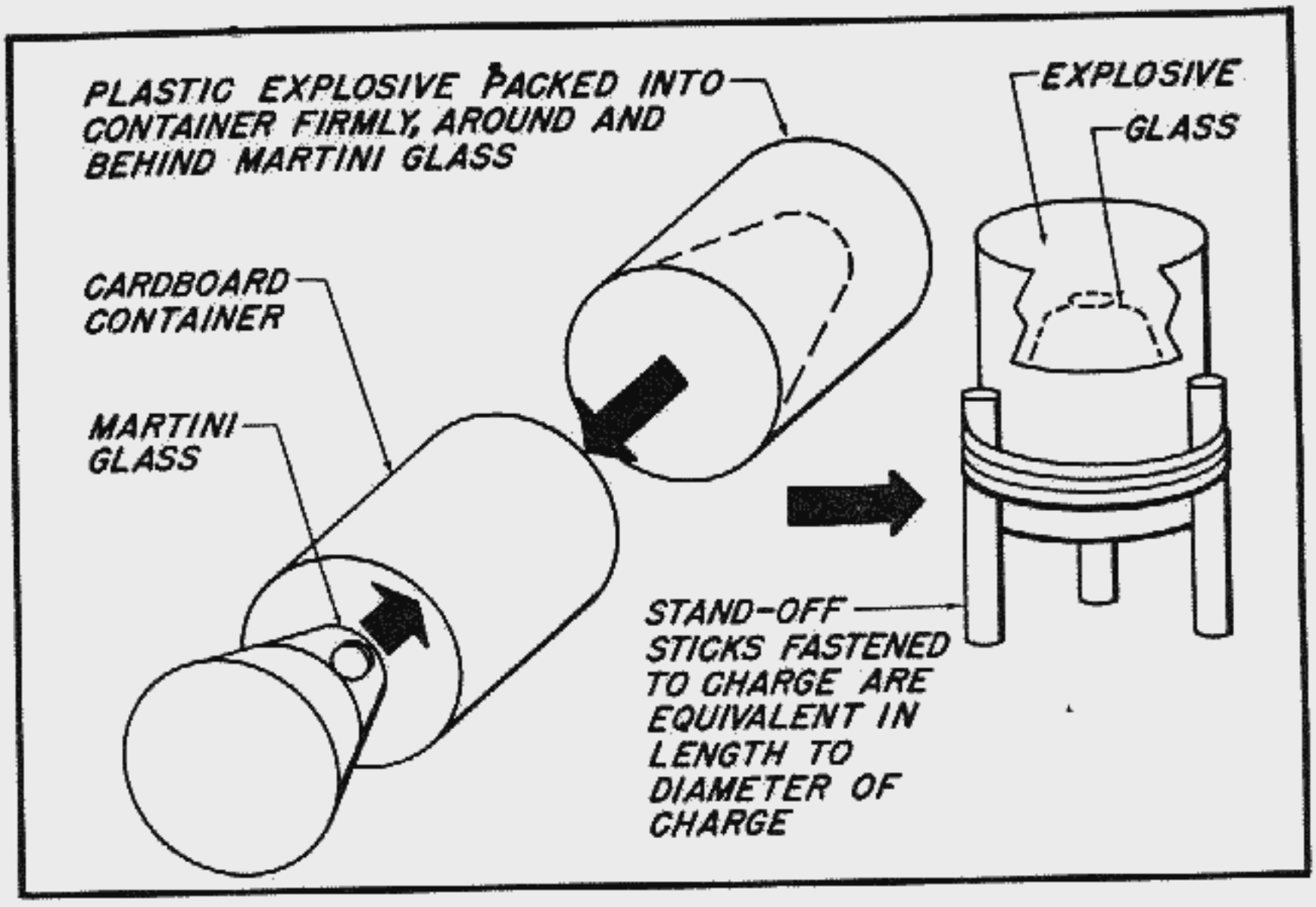

PLASTIC EXPLOSIVE PACKED INTO CONTAINER FIRMLY, AROUND AND BEHIND MARTINI GLASS
CARDBOARD CONTAINER
MARTINI GLASS
EXPLOSIVE
GLASS
STAND-OFF STICKS FASTENED TO CHARGE ARE EQUIVALENT IN LENGTH TO DIAMETER OF CHARGE

Fig. 33 — Martini Glass Charge

of the glass, carefully tamping it with a stick to provide good density and avoid air pockets. For best results the explosive should be packed to a height above the apex of the cone equal to the height of the cone itself. To conserve explosive, the top of the charge may be dome shaped.

4. Tape, wrap, or bind the whole charge to insure that it remains in a firm condition.

5. This charge should be elevated from the target approximately the same distance as the diameter of the mouth of the cone so the shock waves will have room in which to focus. This stand-off can be provided by taping or tying to the charge three sticks to form a tripod. See Figure 33. With this system of placement, the charge would be placed directly over the most vital part of the target. With a vertical target, a counterweight system of placement could be employed. See Figure 34.

The charge should be primed with a blasting cap placed in the center of the rear of the charge. Do not insert the cap so far that it touches the top of the glass cavity. Tape or tie the cap in a firm upright position so it will not become dislodged.

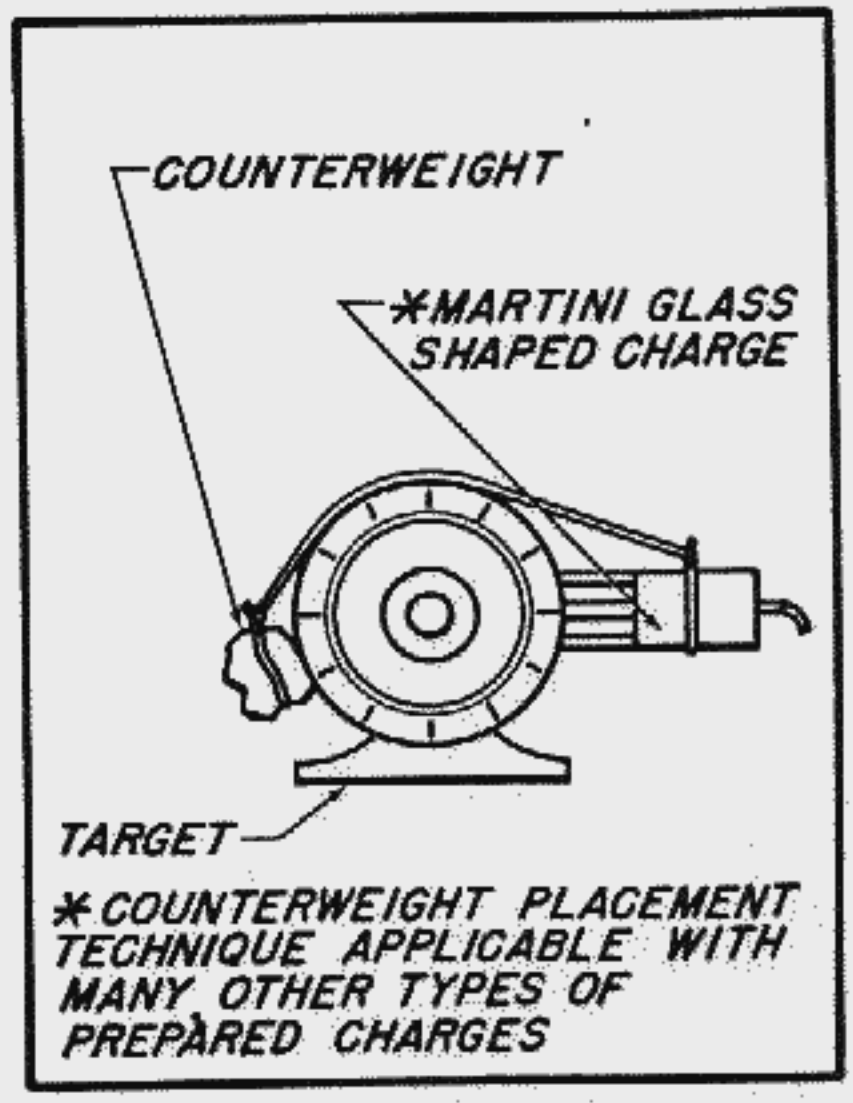

COUNTERWEIGHT
*MARTINI GLASS SHAPED CHARGE
TARGET
*COUNTERWEIGHT PLACEMENT TECHNIQUE APPLICABLE WITH MANY OTHER TYPES OF PREPARED CHARGES

Fig. 34 — Counterweight Placement

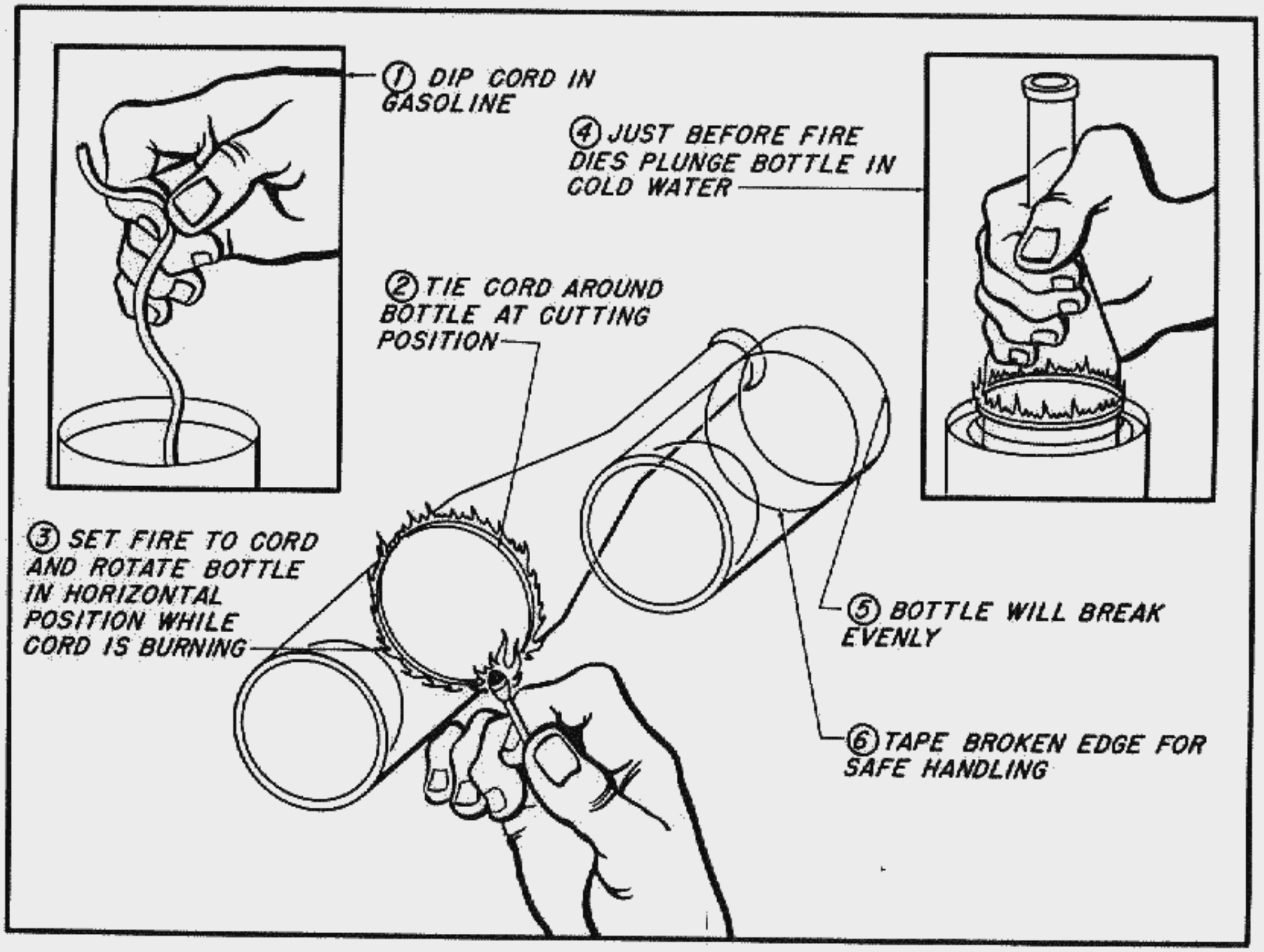

① DIP CORD IN GASOLINE
② TIE CORD AROUND BOTTLE AT CUTTING POSITION
③ SET FIRE TO CORD AND ROTATE BOTTLE IN HORIZONTAL POSITION WHILE CORD IS BURNING
④ JUST BEFORE FIRE DIES PLUNGE BOTTLE IN COLD WATER
⑤ BOTTLE WILL BREAK EVENLY
⑥ TAPE BROKEN EDGE FOR SAFE HANDLING

Fig. 35 — Cutting Wine Bottle

Wine Bottle Shaped Charge

The bottom portion of a wine bottle which has a dome or conical shaped cavity can be used in the same way as a martini glass to construct a cone shaped charge.

MATERIALS: Wine bottle with a cavity base, tubular container, sticks, tape or string, mop string, fiber cord or shoelace, gasoline, bucket of cold water, plastic explosive.

PREPARATION:

1. Remove labels from bottle.

2. Soak mop string or shoelace in gasoline and tie it around the bottle at the point to be cut. See Figure 35.

3. Grasp the bottle by the neck, light the string, and rotate the bottle on a horizontal plane while the string is burning.

4. When the burning starts to die out plunge the bottle into a bucket of cold water. The bottle should crack and separate easily along the line of the string.

5. Cover the sharp edges with tape or rags to protect your hands.

From here on the glass container is used in the same fashion as the martini glass to construct a shaped charge. See Figure 36.

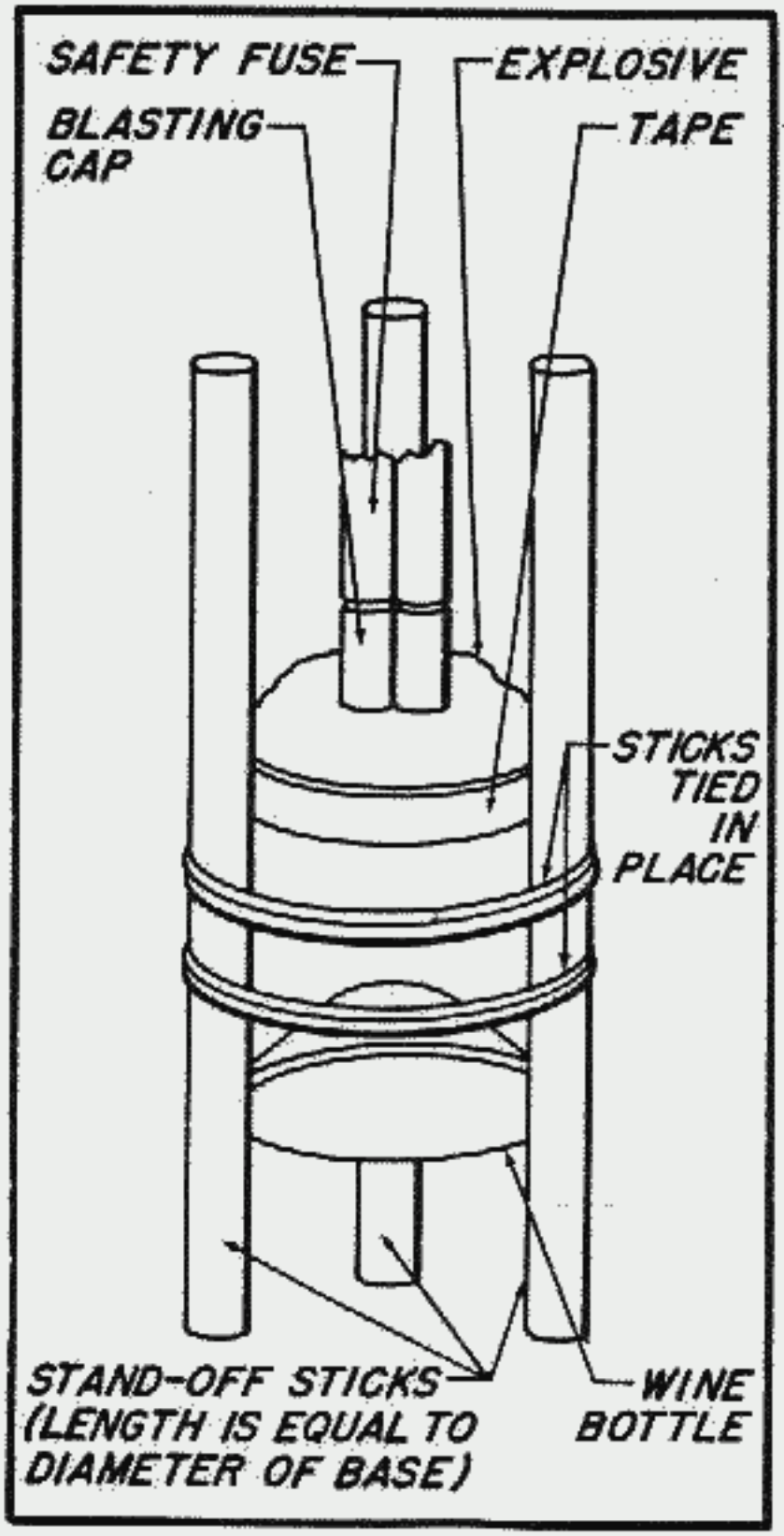


Fig. 36 — Wine Bottle Charge

PLATTER CHARGE

The platter charge technique is a good one to use in situations where it is possible to get near the target but not possible to place a charge directly on it. The charge uses high explosive to hurl a heavy piece of steel at great velocity. It is effective against such targets as transformers, generators, fuel storage containers, and vehicles. It can be fired horizontally or used as an improvised mine.

At close range the platter will penetrate about 1 inch of mild steel. Or it will penetrate woven steel (chain link) fencing and continue on with enough velocity to do severe damage to a target beyond. It is effective at ranges up to 100 feet or more, although at this distance sighting becomes a problem unless the target is a very large one.

MATERIALS: Paper, tape, cloth, tin or cardboard container, steel plate, primacord, blasting cap, plastic explosive.

PREPARATION:

1. Select a piece of steel plate at least 1/4 inch thick and 4 inches or more on a side. A 3 to 5 pound plate is about right.

2. Pack plastic explosive densely against one side of the plate, completely covering it. Use about the same amount of explosive as the weight of the plate.

3. Secure the explosive firmly to the plate with cloth, paper, tape, or string. A firmer charge can be made if a cardboard or metal container is fashioned to hold the explosive in shape behind the plate.

The charge may be primed with a blasting cap or a primacord triple roll knot. The cap or knot should be embedded in the center of the explosive behind the plate but not pushed in so far that it touches the plate. See Figure 37.

If the charge is to be fired horizontally at a target it should be solidly supported above the ground on a box or tied to a stake or tree and "bore sighted" with the plate side toward the target. See Figure 38.

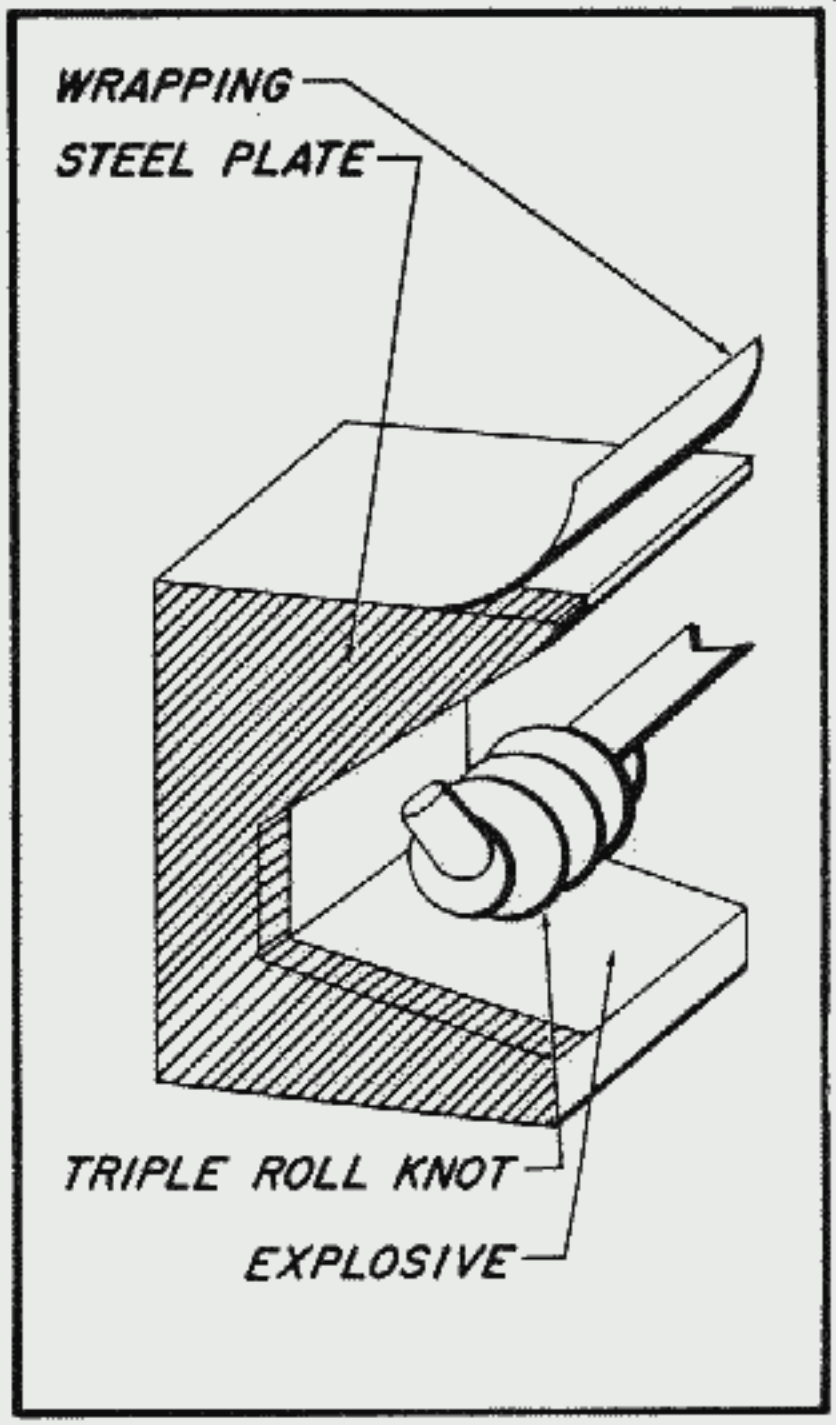


Fig. 37 — Platter Charge

When used as an improvised mine, the charge should be buried just under the surface of the ground, plate side up. It should be primed with a primacord lead to an approbe primed with a primacord lead to an appropriate firing device. Placement should be such that when the firing device is initiated the charge will be detonated under the engine, passenger compartment, or the fuel tank of the target vehicle. See Figure 39.

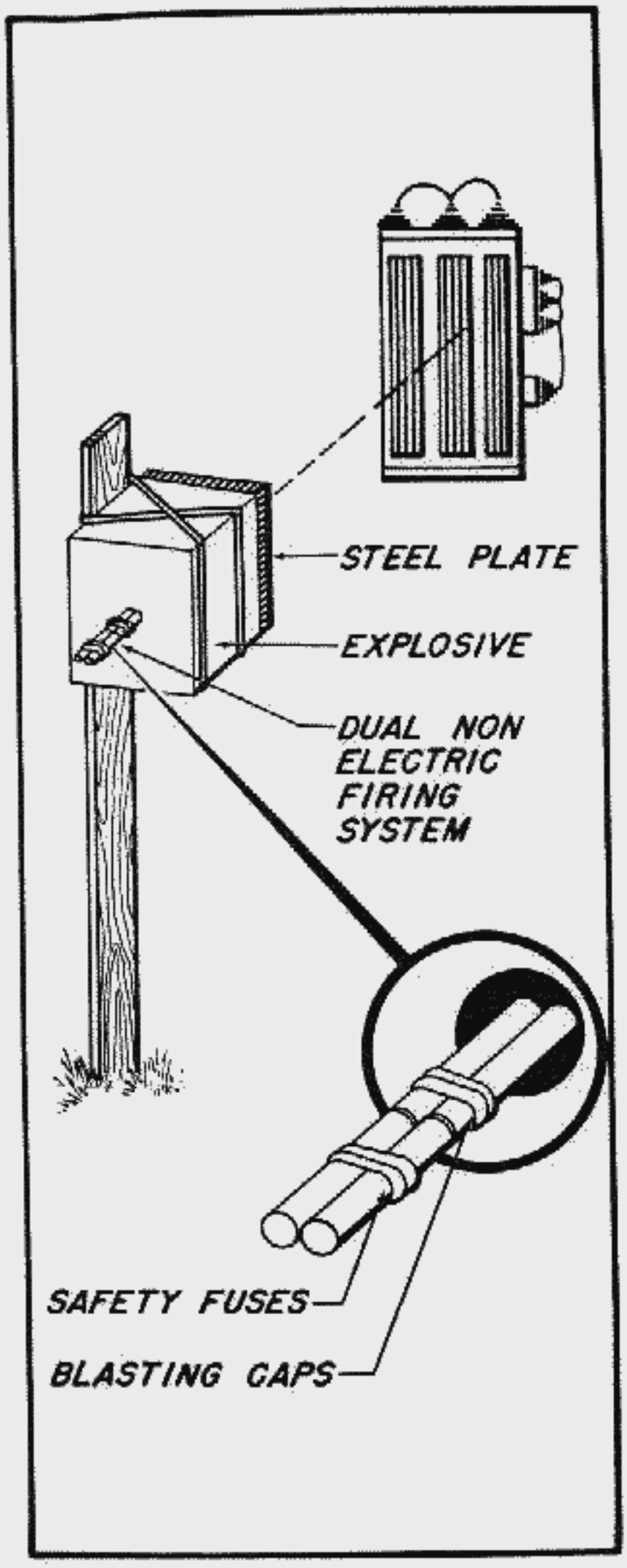


Fig. 38 — Platter Charge Placement

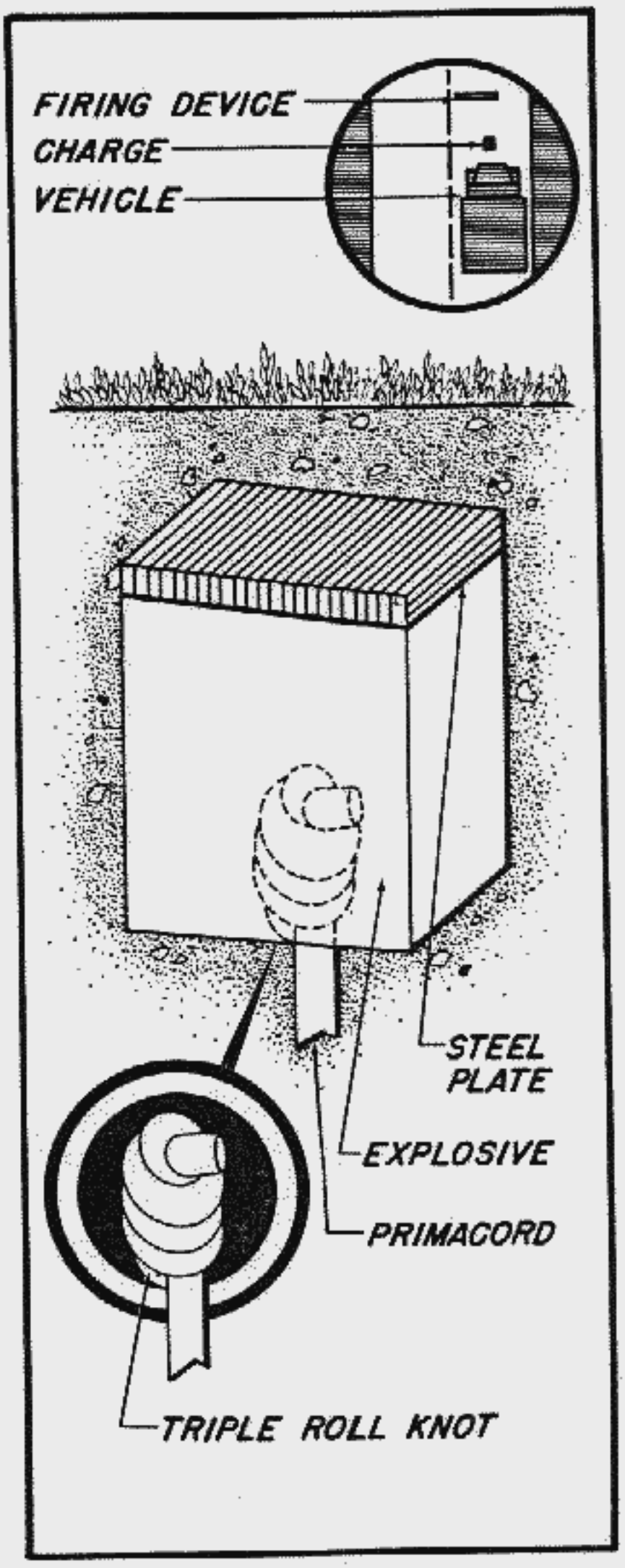


Fig. 39 — Platter Charge Mine

COUNTERFORCE CHARGE

The counterforce effect is obtained by placing two identical (earmuff) charges on exact opposite sides of a target and detonating them simultaneously. The detonation produces a collision of shock waves within the target with severe destructive effect.

The main value of the counterforce technique is that it requires only half the explosive needed to accomplish the same result using standard formulas and placement. For example, a 14 inch diameter timber which requires 3-3/4 pounds of plastic explosive to cut conventionally can be sheared in two with counterforce charges of 3/4 pound each. Reinforced concrete piers 2 feet by 2 feet which can be broken conventionally by 17 pounds of explosive can be broken by counterforce charges of 4 pounds each.

Counterforce charges are most effective against targets which contain no air spaces and which have a high degree of consistency in internal composition, so that the opposing detonation waves encounter the same substances on their way to the midpoint of the target. Solid wood and concrete targets are more vulnerable to the shattering effect of the counterforce charge than are most metal targets.

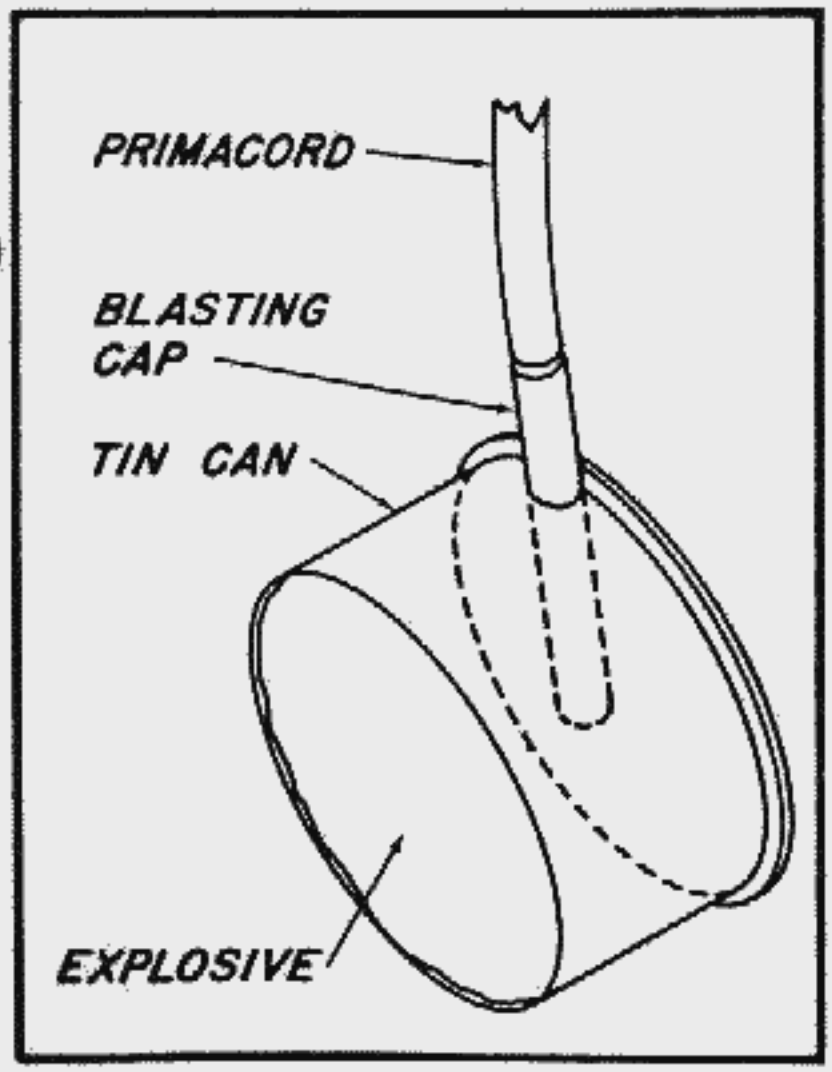


Fig. 40 —Counterforce Charge

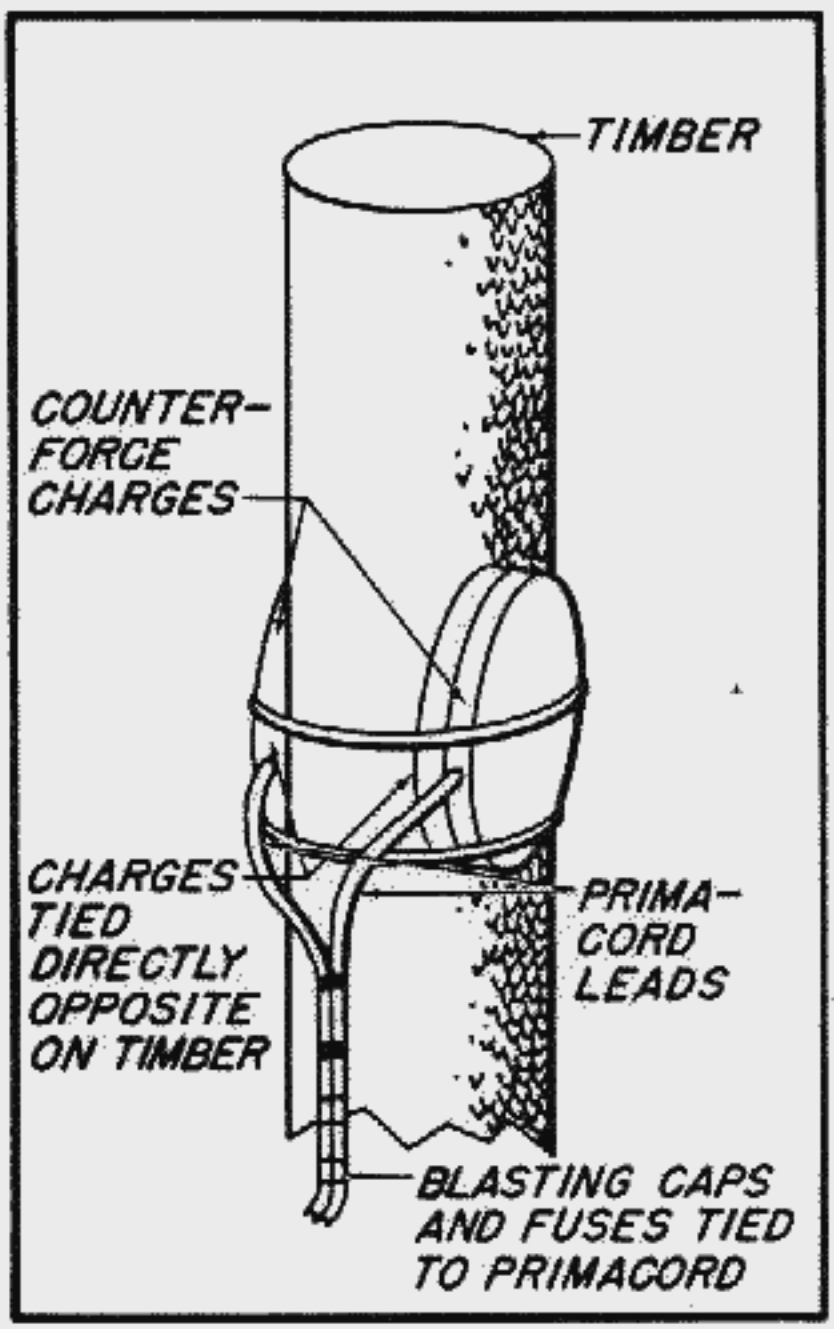


Fig. 41 — Counterforce Charge Placement

The counterforce technique requires care in preparation and placement on the target. It should, therefore, be restricted to situations where the explosive saving is necessary and conditions permit the additional time on the target required.

MATERIALS: Tape, cord, containers for explosive, primacord, blasting caps, plastic explosive.

PREPARATION:

1. Pack plastic explosive densely into two

identical containers -- such as jar lids with an adequate lip or the bottom portions of tin cans. The size of the containers and the amount of explosive will depend upon the type and size of the target. Potency of the charge is increased more, proportionately, by widening its diameter than by making it thicker.

2. Make a hole in the rim of the containers, near the back side of the charge, through which a blasting cap can be inserted.

3. Cut two pieces of primacord of exactly equal length, at least 6 feet, and crimp a non-electric blasting cap to one end of each. Tape or tie the other ends of the primacord together.

Priming is best done at the target. Insert a blasting cap through the hole in the rim of each charge until the business end of the cap is in the center of the charge. See Figure 40.

Place the charges on exact opposite sides of the target. This may be done by taping or tying them into place (see Figure 41) or by suspending them over the target on a string and permitting them to counterbalance each other.

Attach a suitable firing system to the taped ends of the primacord.

DIAMOND CHARGE

The diamond charge technique utilizes colliding shock waves within an explosive charge to obtain a cutting or shearing effect. While it may be used to cut through any material, it is most effective against steel, especially cylindrical steel members such as shafts. It must be carefully prepared and placed but it does permit a considerable saving in explosive over standard charges and placement.

MATERIALS: Paper or cloth, tape, blasting caps, primacord, plastic explosive.

PREPARATION:

1. Construct a diamond shaped pattern on paper or cloth. The long axis of the diamond should be the same length as the circumference of the target -- plus a couple of extra inches to make up for "loss" of length when the charge is wrapped around the target. (NOTE: If you are up on your math you can allow an extra inch for every inch of the diameter of the target.) The short axis of the diamond should be half the length of the long axis.

2. Slice layers of plastic explosive at least 1/4 inch thick with a sharp knife. Make the slices as even in thickness as possible, being careful not to destroy the density of the explosive.

3. Place these layers of explosive over the diamond pattern until it is fully covered. Push the slices firmly together, leaving no air gaps in between, and trim off any edges extending beyond the pattern.

4. Cover the charge with another piece of paper or cloth, fold over the edges and tape tightly to retain the charge in a flat diamond shape. See Figure 42.

5. Cut two pieces of primacord of exactly equal length, crimp a nonelectric blasting cap to one end of each and bind the other ends together with string or tape.

To use on a steel shaft or bar, wrap the charge completely around the target so the two points of long axis meet, and tape or tie

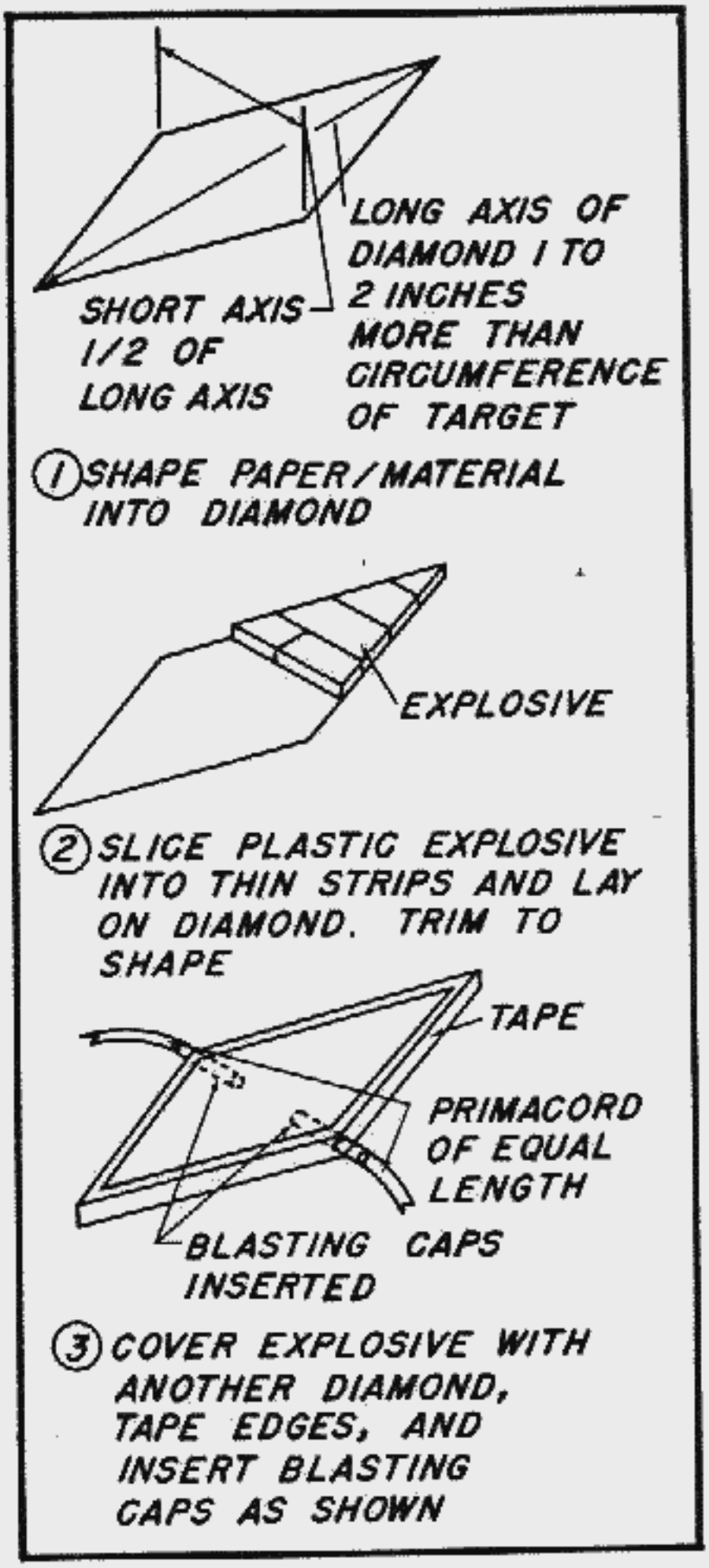

LONG AXIS OF DIAMOND 1 TO 2 INCHES MORE THAN CIRCUMFERENCE OF TARGET
SHORT AXIS 1/2 OF LONG AXIS
(1) SHAPE PAPER/MATERIAL INTO DIAMOND
EXPLOSIVE
(2) SLICE PLASTIC EXPLOSIVE INTO THIN STRIPS AND LAY ON DIAMOND. TRIM TO SHAPE
TAPE
PRIMACORD OF EQUAL LENGTH
BLASTING CAPS INSERTED
(3) COVER EXPLOSIVE WITH ANOTHER DIAMOND, TAPE EDGES, AND INSERT BLASTING CAPS AS SHOWN

Fig. 42 — Diamond Charge

it snugly in position. See Figure 43. The points should just meet, but a slight gap or overlap is not critical. The cutting action of the charge will be along the line of the long axis of the charge.

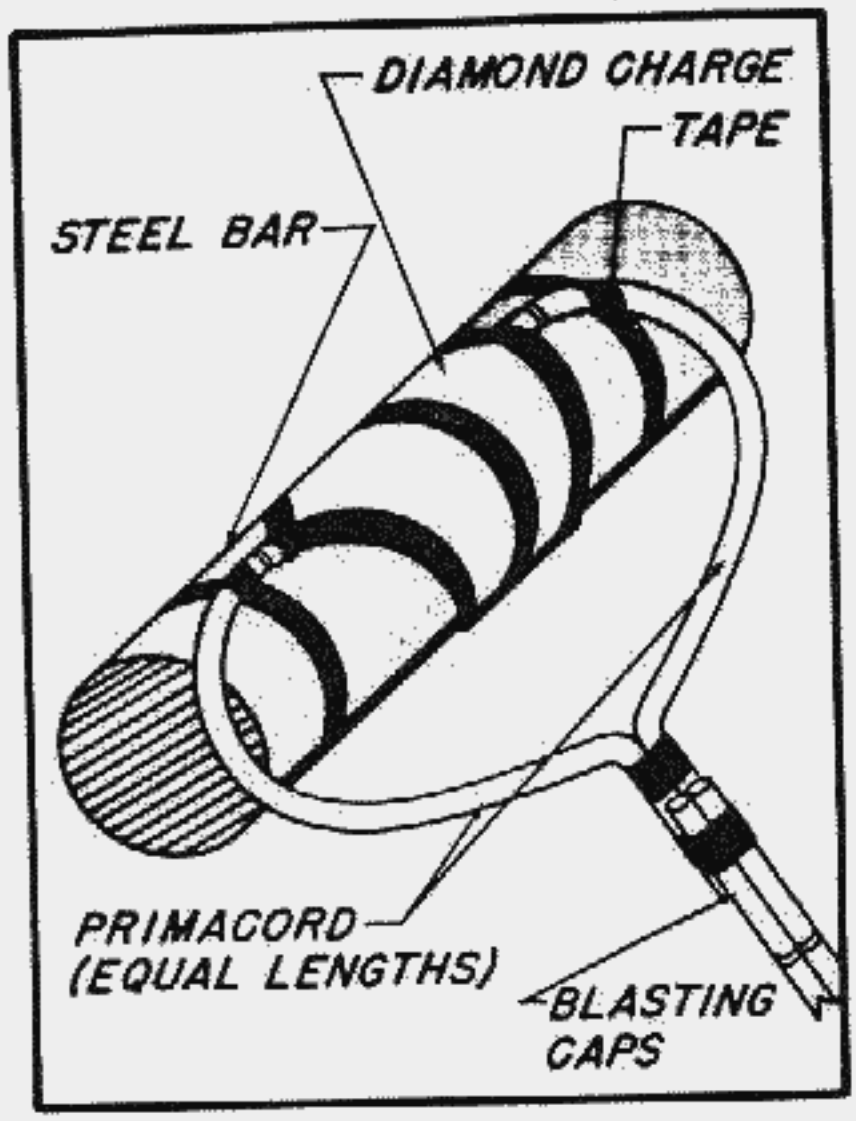


Fig. 43 — Diamond Charge Placement

To prime, insert a blasting cap into each point of the SHORT axis. Be sure each cap is embedded to an equal depth in the explosive and is secured firmly in place.

Attach a suitable firing system to the taped ends of the primacord.

CABLE CUTTER

This technique provides a way of cutting overhead communitions or power cable with explosives placed from the ground and not easily removed if discovered.

MATERIALS: Tin can or bottle, sand, stones, strong cord, TNT or plastic explosive, nonelectric blasting cap, delay firing device (time pencil or time fuse).

PREPARATION:

1. Prepare a charge of TNT or plastic explosive 1/2 to 1 pound in weight.

2. Prepare a counterweight approximately 1-1/2 times the weight of the charge. The counterweight should be longer than the charge and cylindrical in shape to permit it to slide or roll over the target cable easily. A tin can filled with rocks, a bottle filled with sand, or a section of rod or cable will work very nicely.

3. Lay the charge and the counterweight parallel to each other about a foot apart and tie the top and bottom ends of the charge to the top and bottom of the counterweight with strong cord and non-slip knots. See Figure 44.

4. Attach a wire loop securely to each end of the counterweight. Grenade fuse pull rings are ideal, or the rings can be fashioned by bending nails or stiff wire into loops.

5. Cut a throwing line of fairly heavy smooth cord about four times as long as the distance from the ground to the target cable. The suspension lines of a parachute are excellent if available.

6. Pass one end of the throwing line through the two loops on the counterweight and pull it through until the ends of the line are equal in length. To these free ends securely attach a throwing weight such as a rock or chunk of metal.

7. Leaving the charge and counterweight on the ground underneath the target cable, and the excess of the throwing line neatly coiled so the line will run out easily, pitch the throwing weight over the cable and allow it to descend to within reach. See Figure 44.

8. Now prime the charge with a nonelectric blasting cap and a delay device (time pencil or safety fuse) and initiate the delay. Dual priming is advisable, particularly if the time pencil delay is used.

9. Remove the throwing weight from the ends of the throwing line, and hoist the counterweight and the charge up to the cable. Ease the counterweight over the cable and down until the charge is snug up against the cable. See Figure 44.

10. Separate the ends of the throwing line and by pulling gently on one end ease the line through the rings on the counterweight and retrieve it. See Figure 44. The charge and counterweight are left suspended on the cable and the throwing line can be used for placement of other charges along the cable if desired.

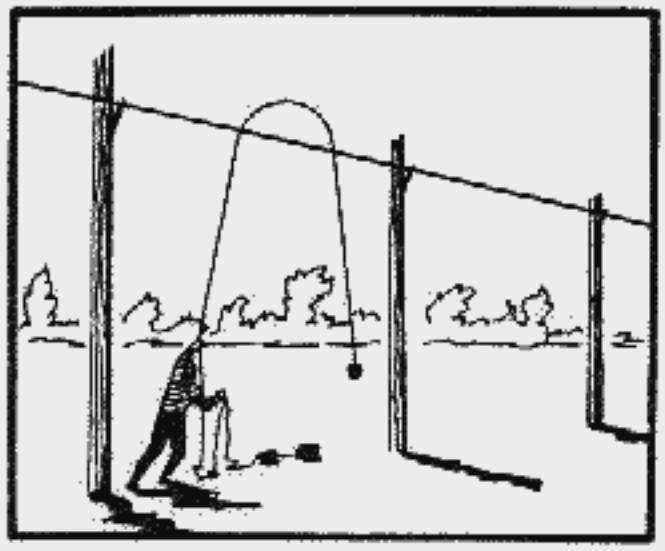
PRECAUTIONS:

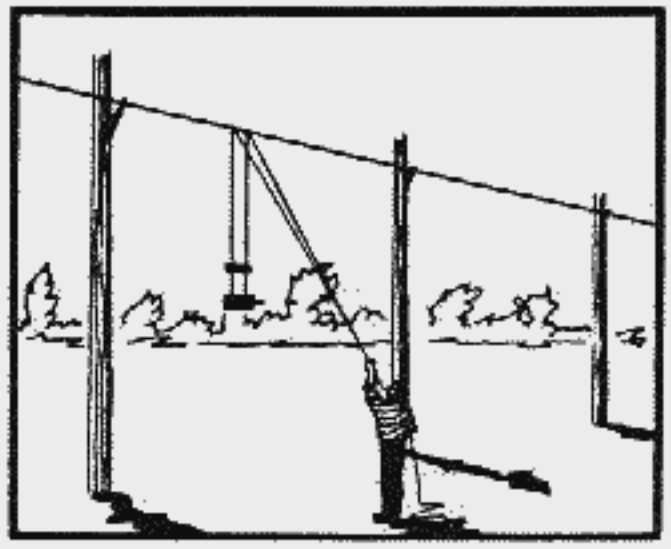
a. Never use a conducting material such as wire for a throwing line.

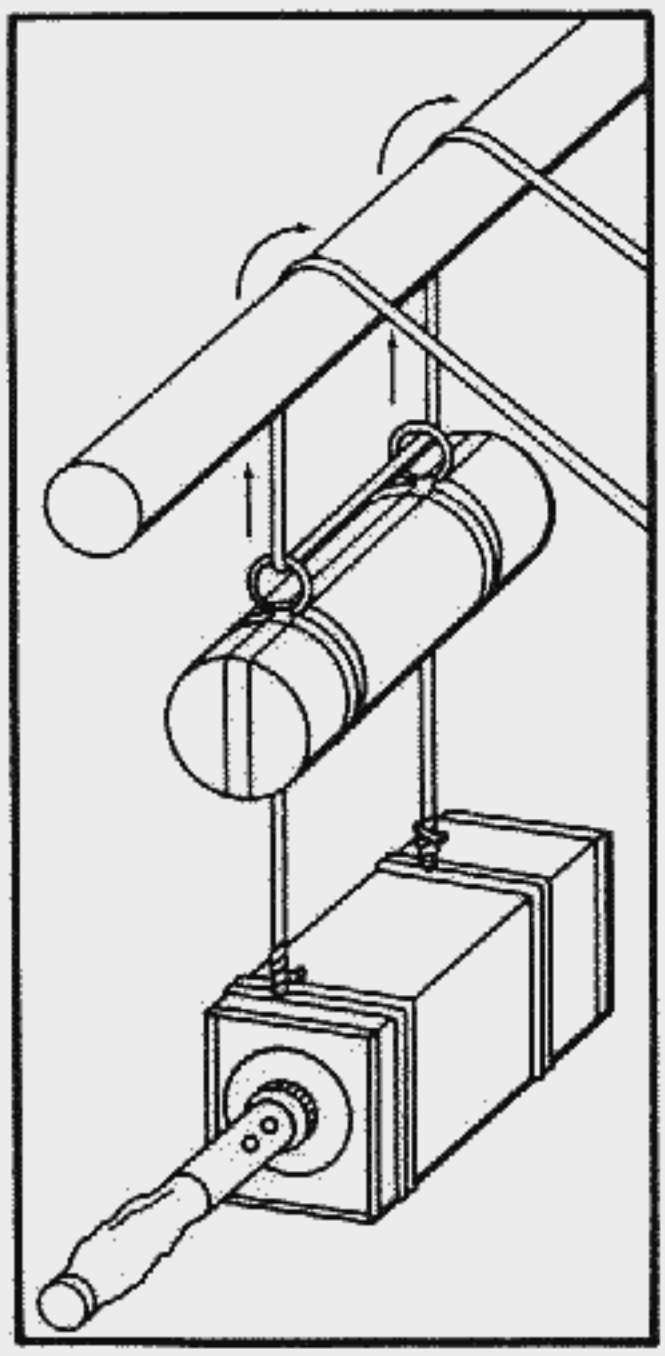
b. Never attack high power lines by this method in wet weather, because a wet throwing line could act as a conductor.

c. Be sure to allow enough delay time after the charge is placed for the operator to retire to a safe distance. When cut, the cable may whip around in any direction.

d. While not too pertinent for this technique since the operator remains on the ground, a good rule to observe with any high voltage equipment is never approach it closer than the length of the largest visible insulator used on the equipment.







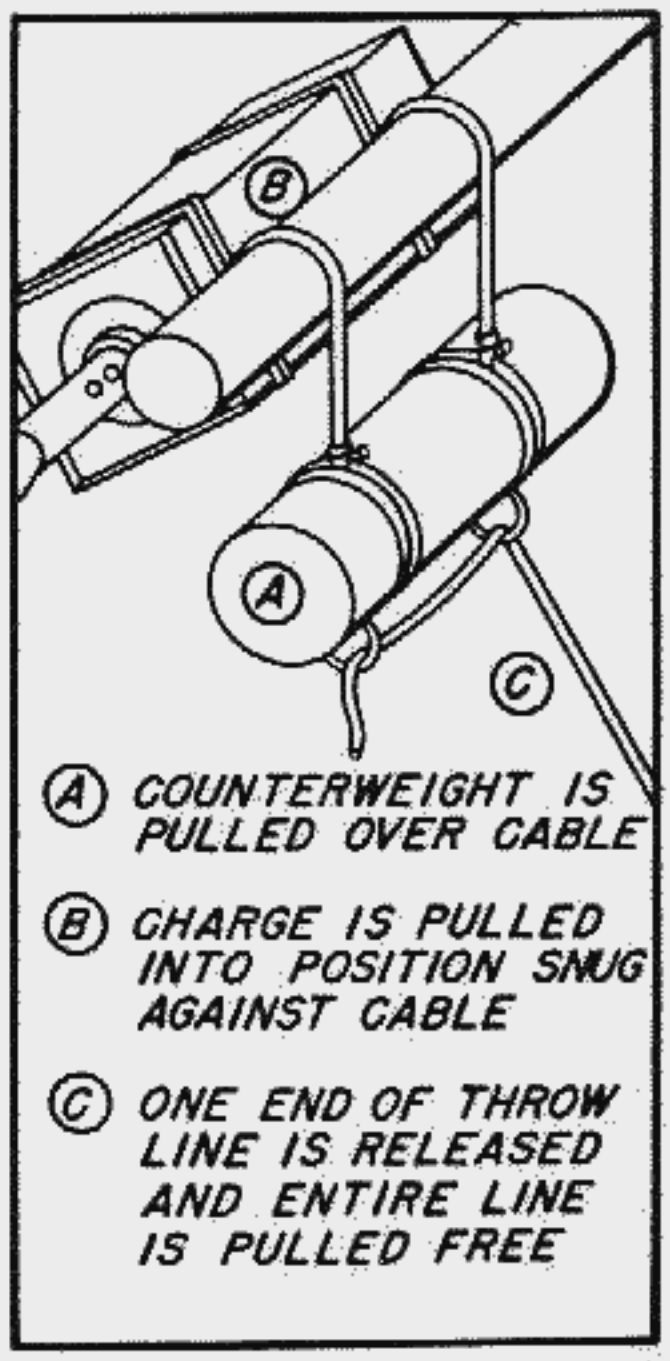

A
B
C
A COUNTERWEIGHT IS PULLED OVER CABLE
B CHARGE IS PULLED INTO POSITION SNUG AGAINST CABLE
C ONE END OF THROW LINE IS RELEASED AND ENTIRE LINE IS PULLED FREE

Fig. 44 — Cable Cutter

AMBUSH OR ANTIPERSONNEL CHARGES

Scatter Charge

This charge is very effective as an ambush weapon against personnel on foot or in unarmored vehicles. It also may be used against communications equipment such as radar consoles or telephone switchboards.

When detonated the charge throws a heavy pattern of metal fragments toward the target at which aimed. The range is not great -- perhaps 50 yards maximum -- but the fragments disperse rapidly for broad coverage at ranges of 10 to 20 yards. The effect is devastating to both equipment and morale. Fragments will penetrate metal of an unarmored automobile or truck, corrugated sheet metal or light wooden walls such as those of a mess hall or barracks.

MATERIALS: Metal fragments (nails, washers, bolts, nuts, etc.), rags, wire, tape, or string, container, primacord and/or blasting caps, plastic explosive or dynamite.

PREPARATION:

1. Pack explosive densely into the bottom one fourth of the container. A tin can of about 1 gallon capacity is about ideal for most targets. The container should not be smaller than 1 quart but large diameter cardboard tubes or ordinary pails are satisfactory.

2. Puncture a hole in the bottom center of the container large enough for the insertion of a blasting cap or primacord. If initiation is to be by primacord, the primacord should be inserted through the hole and a triple roll knot tied inside the container. The explosive should then be packed around the knot.

3. If the charge is not to be used in the near future or may be subjected to rough handling, insert a sheet of heavy paper or cardboard over the explosive to keep it separated from the metal fragments to be added later.

4. Fill the remaining three fourths of the container with metal fragments or scraps. See Figure 45. Rocks, glass or other brittle materials are not satisfactory since they will be pulverized by the explosion.

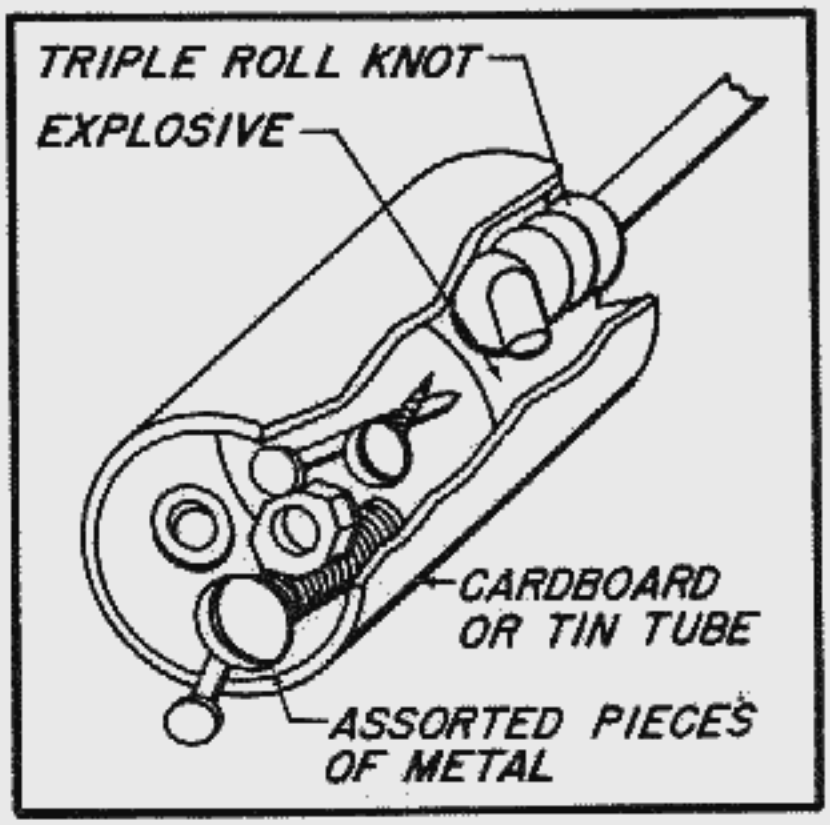


Fig. 45 — Scatter Charge

5. Fasten a cover of cardboard or cloth over the charge to keep the metal fragments from falling out of the container.

For ambush use, the charge should be securely fastened into position above ground, and aimed down the trail or road along which the column of troops or vehicle convoy is expected to appear. It should, of course, be camouflaged. More than one charge may be used and fired simultaneously by using primacord hookup.

Similar charges having much the same effect may be made by using coiled chain (automobile tire chain size), short lengths of barbed wire, or serrated or grooved metal plates which break into fragments when the charge is exploded.

Frag Grenade Ambush

Fragmentarion hand grenades dispersed along a trail or road and camouflaged provide an excellent ambush technique. With a primacord system any number can be fired simultaneously.

MATERIALS: String, wire or tape, fragmentation grenades, primacord, blasting cap.

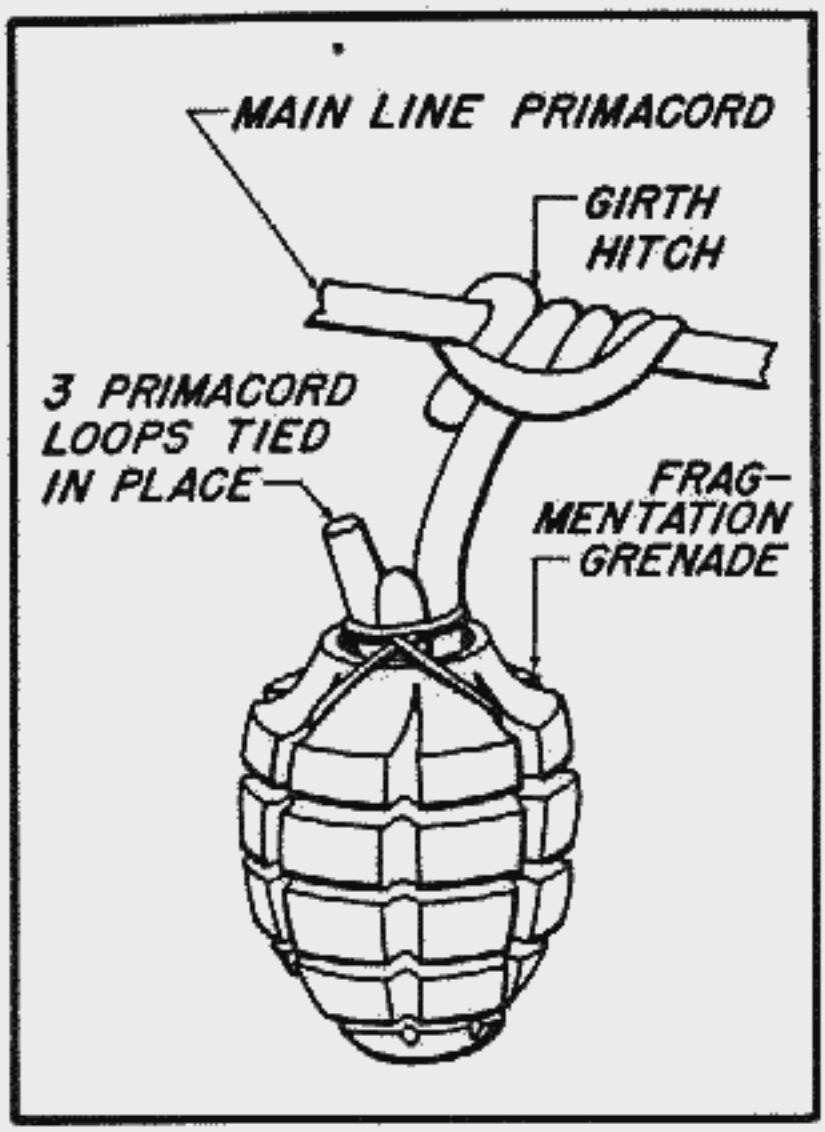


Fig. 46 — Frag Grenade Charge

PREPARATION:

1. Spread the points of the cotter pin safety to prevent accidental dislodging and then unscrew the fuse assembly of the frag grenade with pliers. The fuse may be saved for use as an improvised firing device or the blasting cap may be removed for other uses (see section on improvised detonators).

2. Cut a piece of primacord of whatever length needed to provide a branch line to a primacord main line. Usually about 3 or 4 feet is sufficient.

3. Fold one end of the primacord back on itself two or three times and wedge the folded end tightly into the empty fuse well of the grenade. Fasten the primacord securely to the grenade with wire, string or tape. See Figure 46.

4. Repeat the process for as many additional charges as are needed.

At the ambush site the grenades should be hung in bushes or tied to tree branches alongside the trail or road. If the grenades are placed on the ground (generally not the most effective placement) they should be upright, not lying on the side. Fasten the branch lines from the grenades to a main primacord line with a girth hitch or other tight knot. Attach a blasting cap and suitable firing device to the primacord main line. Camouflage the whole system.

For a heavy ambush the frag grenades may be interspersed with the scatter charge previously described, mortar shells, or with other improvised fragmentation charges.

Improvised Frag Grenade

Although more powerful than military fragmentation grenades, the improvised version described below is not as easily armed and thrown. It is advisable, therefore, to thoroughly test the time fuse used and perhaps to practice with a dummy model of the grenade before attempting to use a live one operationally.

MATERIALS: Metal fragments (nails, washers, bolts, nuts, screws, etc.), rags, string or tape, time fuse, nonelectric blasting cap, 1/2 pound of any high explosive.

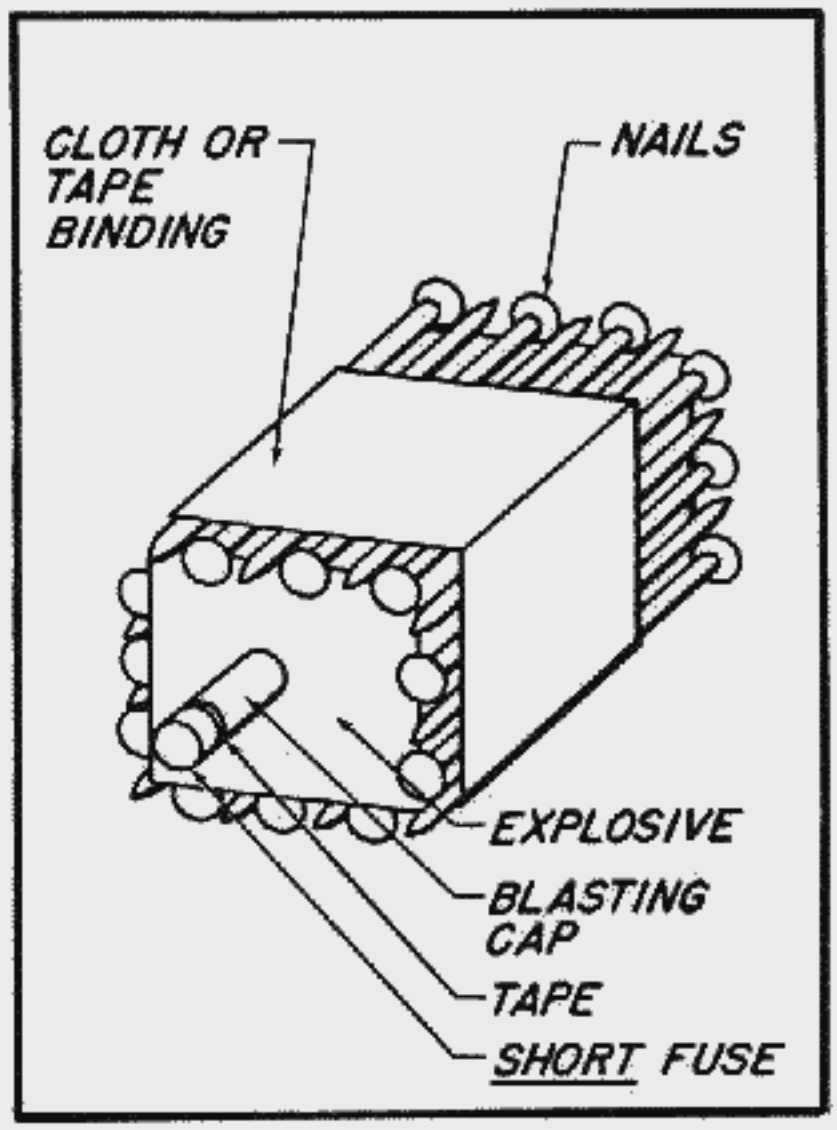


Fig. 47 — Improvised Frag Grenade

PREPARATION:

1. Surround a half pound lump or block of high explosive with metal fragments, leaving a small area clear for the insertion of a blasting cap. Nails may be neatly taped or tied to a block of explosive, as illustrated in Figure 47, or the metal fragments may be placed at random around a lump of explosive and the charge tightly wrapped in a rag or sock. It is important, however, that the charge be comfortable to hold and a handy size to throw.

2. Insert a piece of time fuse as far as it will go into a blasting cap. Mark the fuse about 1/2 inch from the opening of the blasting cap, remove it and cut it off at this mark.

3. Test the burning time of several pieces of fuse of the SAME LENGTH, cut from the SAME ROLL. By counting slowly and steadily, as "one thousand, two thousand, etc.," from the moment the fuse is lit to the time the spark is observed at the other end, a uniform delay of 6 to 7 seconds should be observed. If identical lengths of identical fuse do not burn uniformly, that fuse should NOT be used for this technique.

4. When a safe delay is reliably determined, prepare a firing system for the grenade by double crimping a blasting cap to the selected length of fuse. Wrap a short piece of tape around the joint between the cap and the fuse to prevent any spark from the lighting mechanism (match or fuse lighter) from bypassing the fuse into the blasting cap. Insert the cap into the charge and fasten it tightly in place.

This charge is most effective when an air burst is achieved directly over the target. The grenade should therefore be thrown with only 2 or 3 seconds of delay remaining. This is why it is necessary that the time fuse be fully tested in advance and that the user experiment until he can confidently count out the necessary delay after lighting the fuse.

As with any frag grenade, the user must

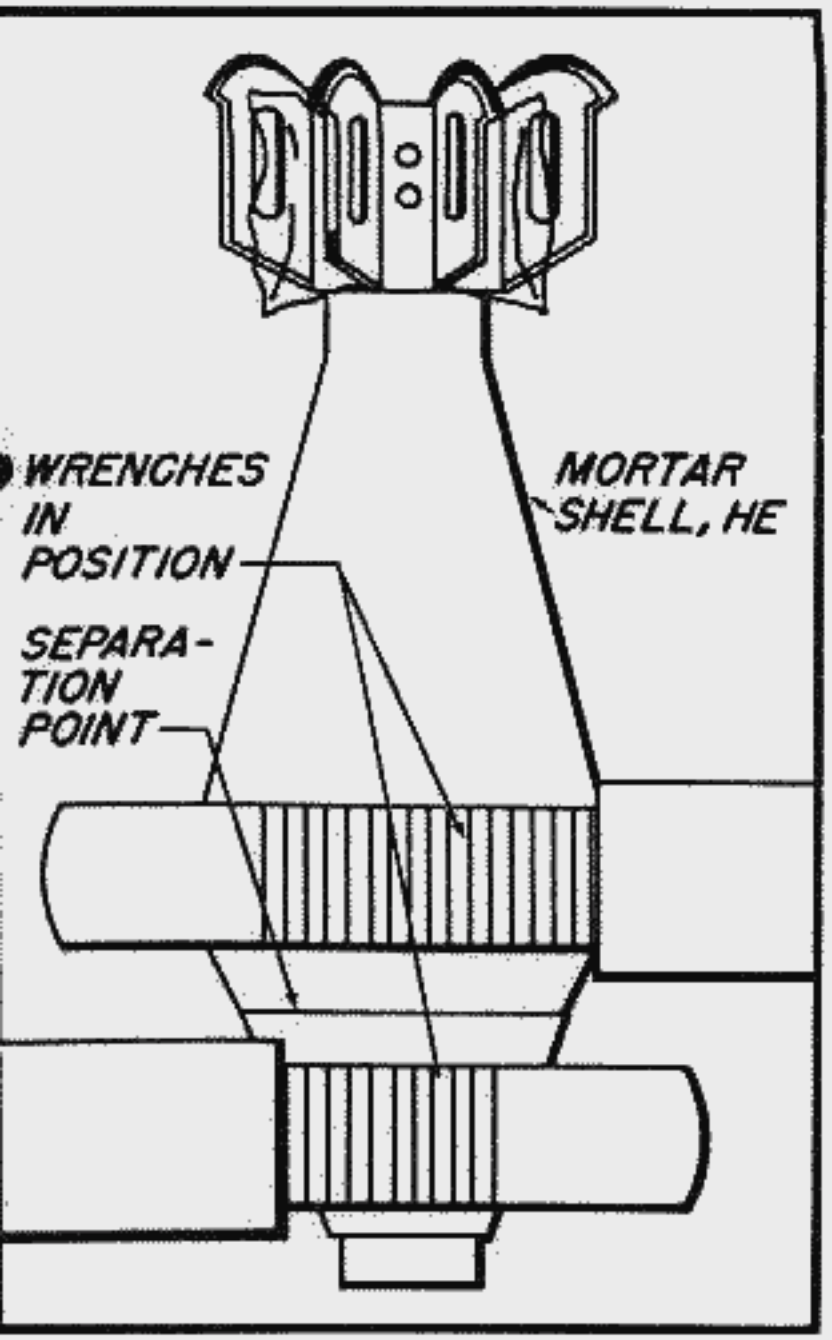


Fig. 48 — Removing Mortar Shell Fuse

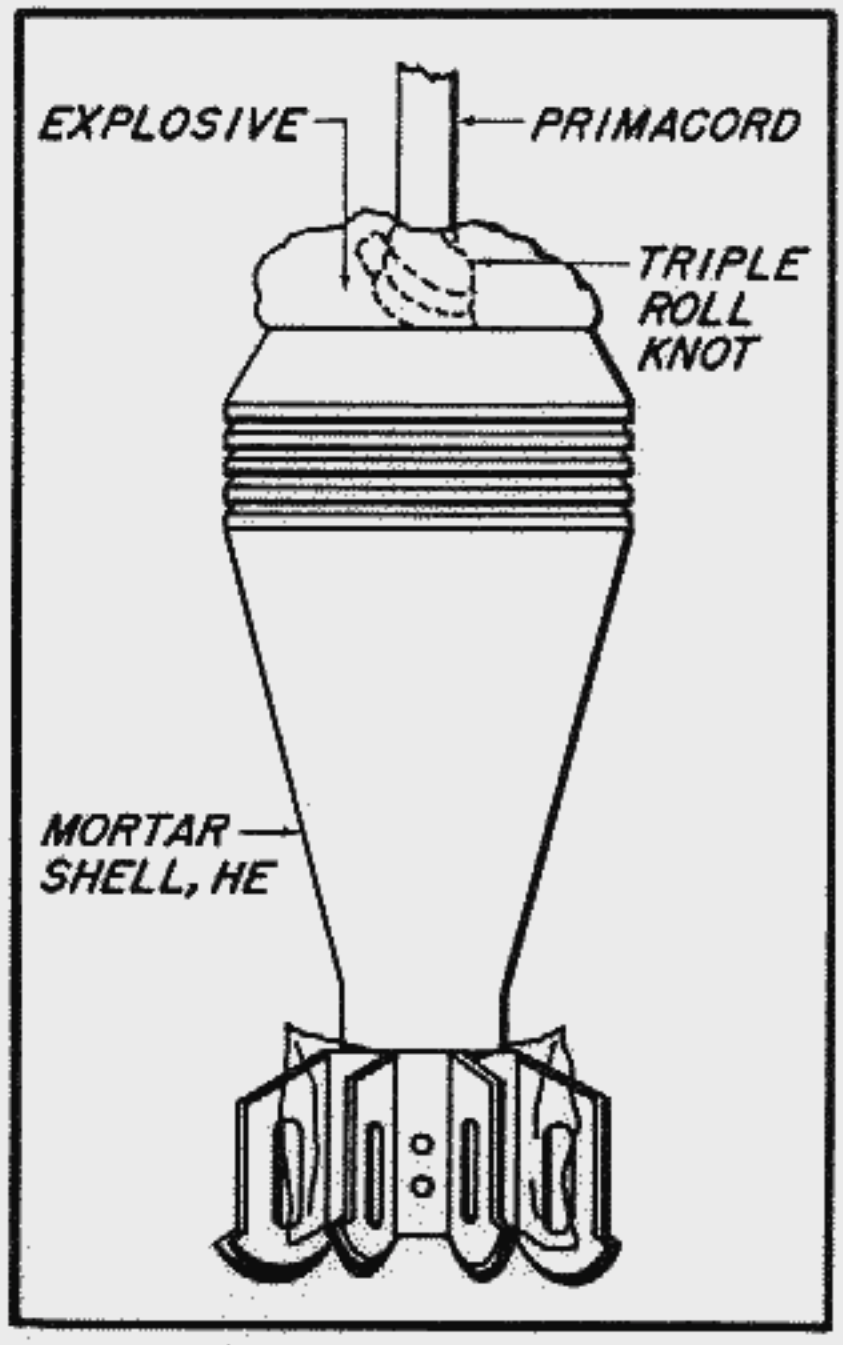


Fig. 49 — Priming Mortar Shell

protect himself from flying fragments. A prone position in a ditch, or shelter behind a tree, stump, or boulder will be sufficient protection.

Mortar Shell Ambush

Mortar shells can be fired as placed ambush charges in the same way as hand grenades. Being more powerful than grenades, they provide an even more lethal antipersonnel or antivehicular technique.

MATERIALS: String, wire or tape, mortar shell, primacord, blasting cap, plastic explosive (optional).

PREPARATION:

Many types of mortar shells are packed unassembled in separate containers. In such cases one need only fill the fuse well with plastic explosive and prime it with a primacord triple roll knot. Others, including U.S. shells, are packed fully assembled. Following are the steps to be taken to prepare a fully assembled shell for use as an ambush charge.

1. Make sure the safety pin is securely in place, then unscrew the fuse assembly from the mortar shell by using one wrench on the shell body and one on the fuse -- working in opposite directions. See Figure 48.

2. Tie a triple roll knot in the end of primacord of whatever length is needed for a branch line. Insert the knot into the open fuse well of the mortar shell, and pack plastic explosive around it. Fasten the explosive and knot in place with tape, wire, or string. See Figure 49.

3. Another way of priming the charge is to use the booster which is present in the fuse assembly instead of plastic explosive. To do this, leave the wrench on the fuse after it is removed from the shell, grip the booster cup with pliers and unscrew the booster from the fuse.

4. Replace the booster in the fuse well, place one turn of primacord tightly on top of the booster and secure it firmly in place with string, wire, tape or rags. The booster and primacord also should be securely fastened to the shell.

Any number of mortar shells may be prepared either with the plastic explosive technique or by using the booster and attached by their primacord branch lines to a main primacord line for simultaneous firing. Or they may be interspersed along a road or trail with frag grenades or other improvised charges.

Vehicle Booby Trap

Here's a safe and quick way of booby trapping an automobile without wiring into the ignition switch.

MATERIALS: Electric blasting cap, explosive.

PREPARATION:

1. Make a hole through a 1/2 pound or larger explosive charge (TNT, dynamite, plastic) so a blasting cap can be inserted all the way through the charge.

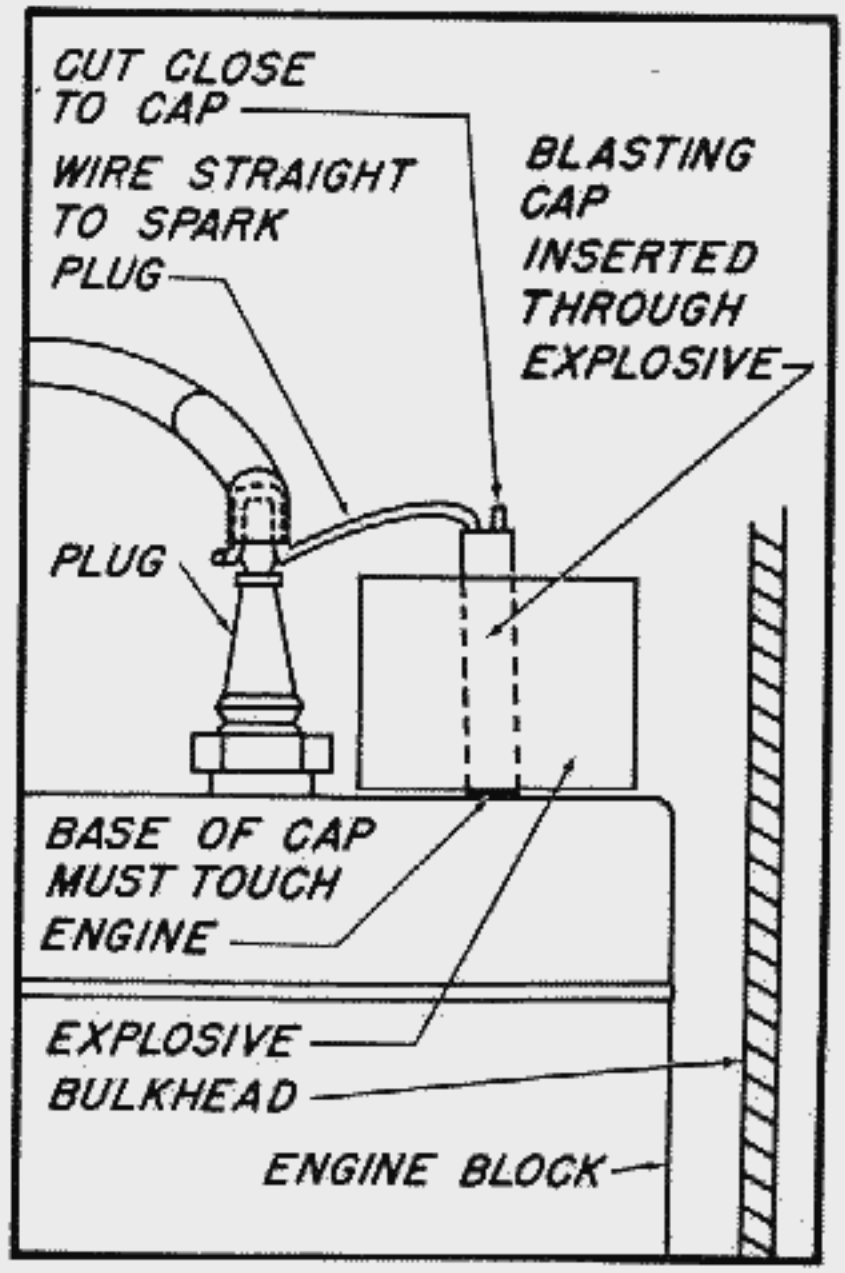


Fig. 50 — Vehicle Booby Trap

2. Snip off one of the two blasting cap wires up close to the cap and discard it.

3. Place the charge securely on the engine block of the target vehicle, as close as possible to the bulkhead of the passenger compartment.

4. Insert the blasting cap through the hole in the explosive so that the tip of the cap touches (is grounded against) the engine block. Except for the tip, the explosive end of the cap should be surrounded by explosive.

5. Stretch the remaining cap wire to the nearest spark plug. Cut off any excess wire, strip the end of the remaining portion and attach it to the top of the spark plug. See Figure 50.

6. Make sure that the cap wire is not near or touching any metal except the spark plug, otherwise there might be an accidental grounding at that point, resulting in a misfire.

The safety feature of this technique lies in the fact that the charge will not be activated until the engine is started, sending a spark through the plug. The ignition switch technique, on the other hand, can be dangerous unless the operator has a circuit tester or is thoroughly familiar with the ignition wiring.

THE 3.5 ROCKET

General

The U.S. 3.5" high explosive antitank rocket (or similar rockets used by other modern military forces) can be cannibalized or altered and used in a variety of improvised techniques. It can be placed as a shaped charge or land mine or it can be launched either electrically or nonelectrically without use of the rocket launcher. Such improvised firing offers the advantages of rigging the rocket as a booby trap or, at least, permitting the operator to be well out of the area before the rocket fires.

Placed Charges

MATERIALS: 3.5" rocket, safety fuse, primacord, blasting cap, plastic explosive.

PREPARATION:

1. Leaving the safety band in place, unscrew the warhead from the rocket with pipe wrenches, or wrench and a vise, as illustrated in Figures 51 and 52.

2. The detonator booster may remain connected to the warhead or it may unscrew as part of the fuse section, depending upon the tightness of the respective threads. If the booster remains connected to the warhead, handle it with care. The exposed red dot on the booster is a stab-sensitive detonator. Cover this with tape or other protection until ready to prime the charge.

3. If the booster remains in the warhead, the charge can be detonated by attaching a blasting cap or primacord across the red dot.

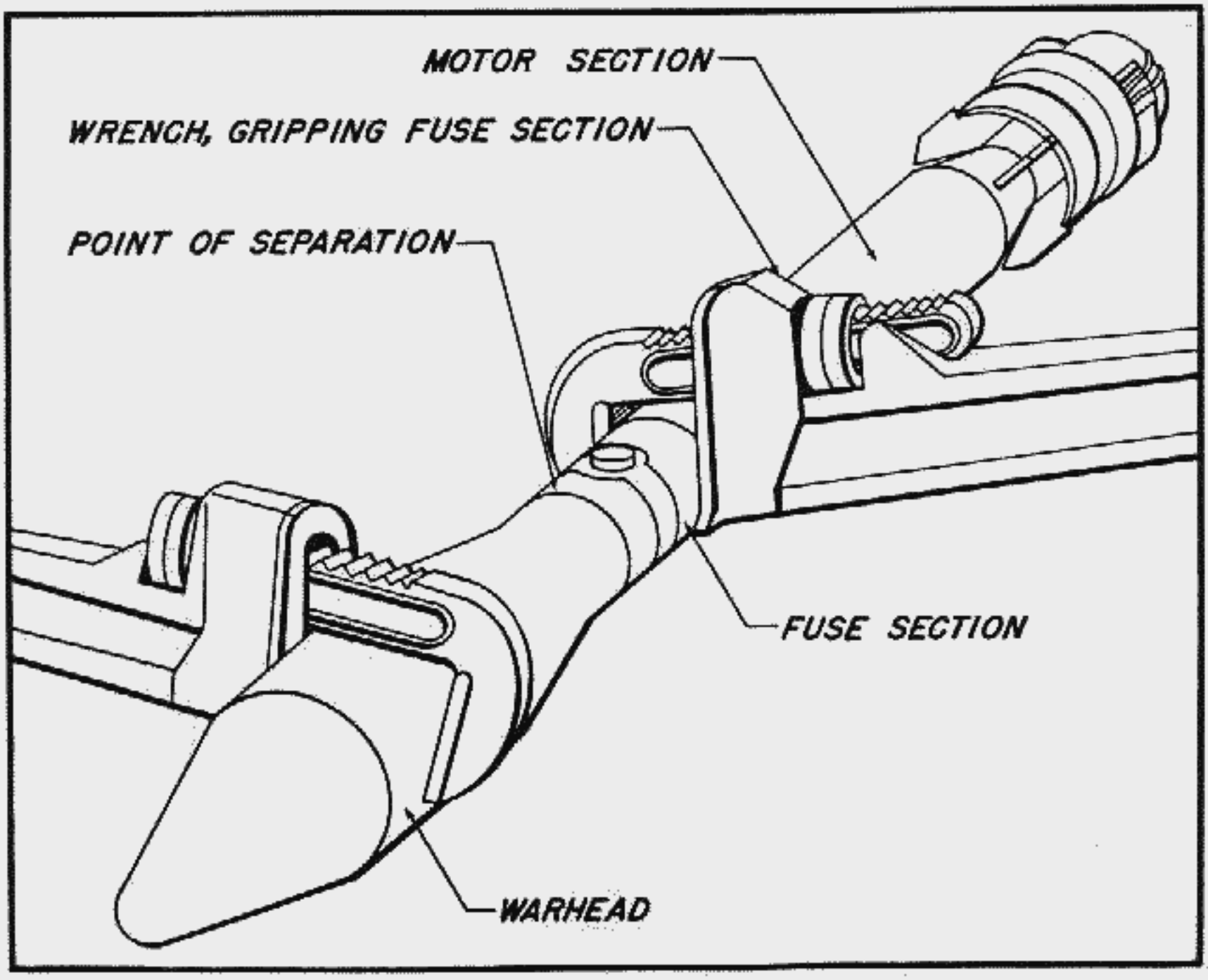


Fig. 51 — Removing Rocket Head

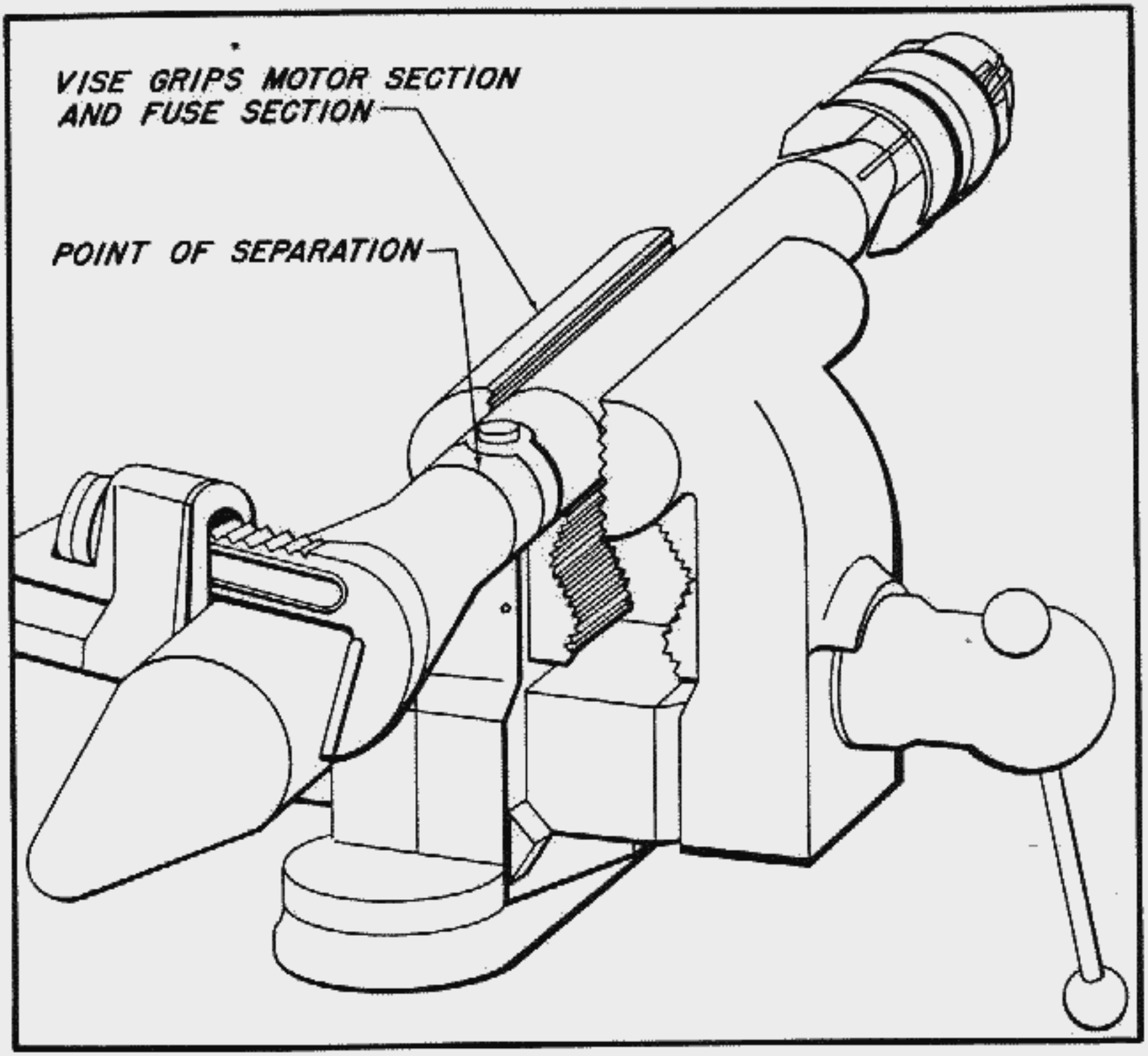


Fig. 52 — Removing Rocket Head

4. If the booster is not used, the warhead may be primed by filling the cavity in the top with plastic explosive, into which is embedded and fastened a blasting cap or a primacord knot.

5. To use as a placed shaped charge, prepare a tripod of sticks taped or tied to the charge to hold it upright on the target as illustrated in Figure 53. The nose of the charge may be directly against the target, or a slight additional standoff can be provided, as illustrated. For awkward shapes such as generators or turbines, the charge can be placed against the side of the target by using a counterweight system. Approximately 15 inches penetration of mild steel can be obtained with a properly prepared 3.5 rocket head shaped charge.

6. To use as a land mine, the charge should be placed and primed as illustrated in Figure 54.

Improvised Electric Launching

MATERIALS: 3.5" rocket, packing tube, downspout, soil pipe or boards, firing wire, batteries.

PREPARATION:

1. First find the two wires in the rocket tail section which disappear through a plastic plug into the rocket motor. (In the current model of the 3.5, these are the two wires covered with clear plastic.)

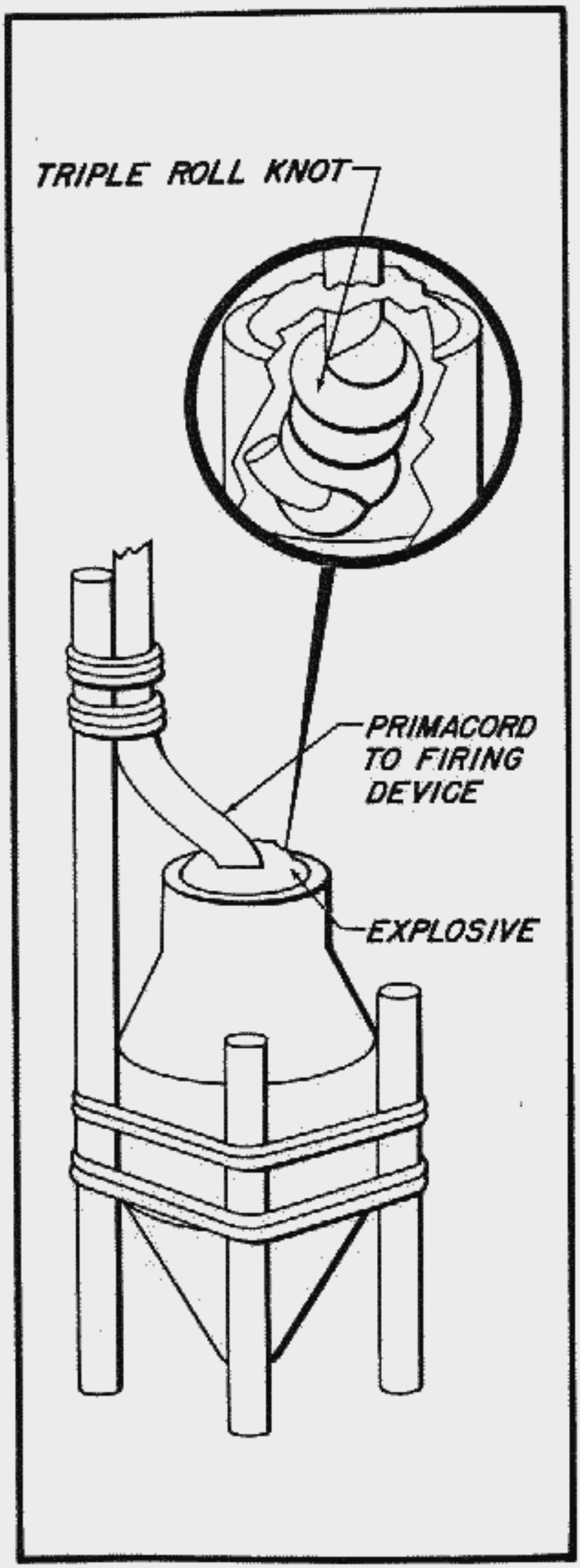


Fig. 53 — Rocket Shaped Charge

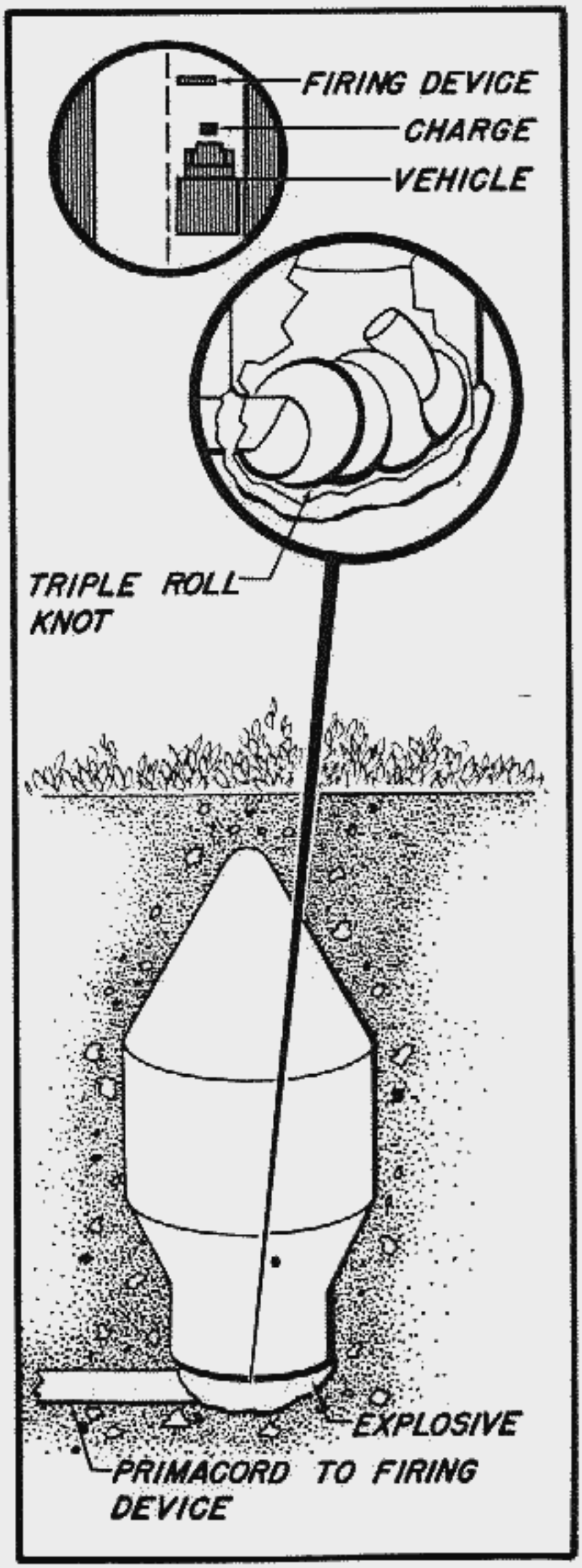


Fig. 54 — Rocket Land Mine

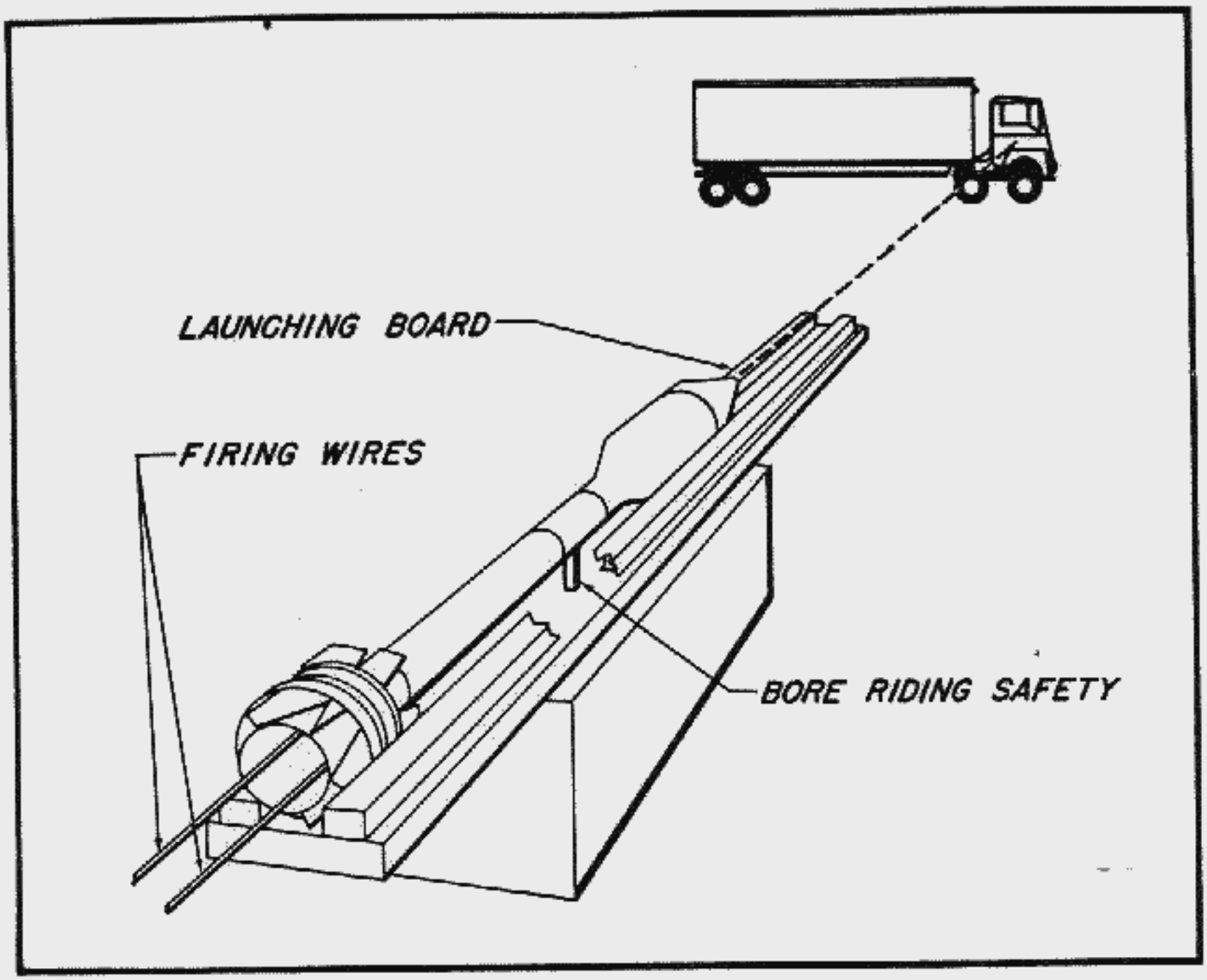


Fig. 55 — Improvised Rocket Launcher

2. Detach the ends of these two wires from any others to which connected and strip the insulation from the last half inch or so. The other wires may be snipped off or just folded out of the way.

3. The rocket may be launched from its own packing tube or other tube (as indicated under "materials," above), or from a flat or V-shaped wooden platform. To prepare for launching, first remove the safety band. The small spring-loaded button under the band is the bore-riding safety. The rocket must be placed in the improvised launcher so that this safety is depressed to a degree which makes it exactly flush with the head and the tail of the rocket. Thus, if the rocket is placed in a tube or on a flat surface, the safety should be on the bottom. If placed in a V-shaped launcher, the safety should be against one of the sides. See Figure 55 for proper placement on an improvised launcher.

4. After the rocket is placed on the launcher and sighted (of which more later), attach firing wires to the rocket wires as illustrated in Figure 56.

5. Apply current with flashlight batteries to fire. To be safe, the operator should not be closer than 50 yards directly behind the rocket when it is fired.

Nonelectric Launching

MATERIALS: 3.5" rocket, packing tube or other launching material as described above, safety fuse, safety matches.

PREPARATION:

1. To prepare the rocket for nonelectric launching, first remove the plastic plug (previously referred to) which blocks the motor

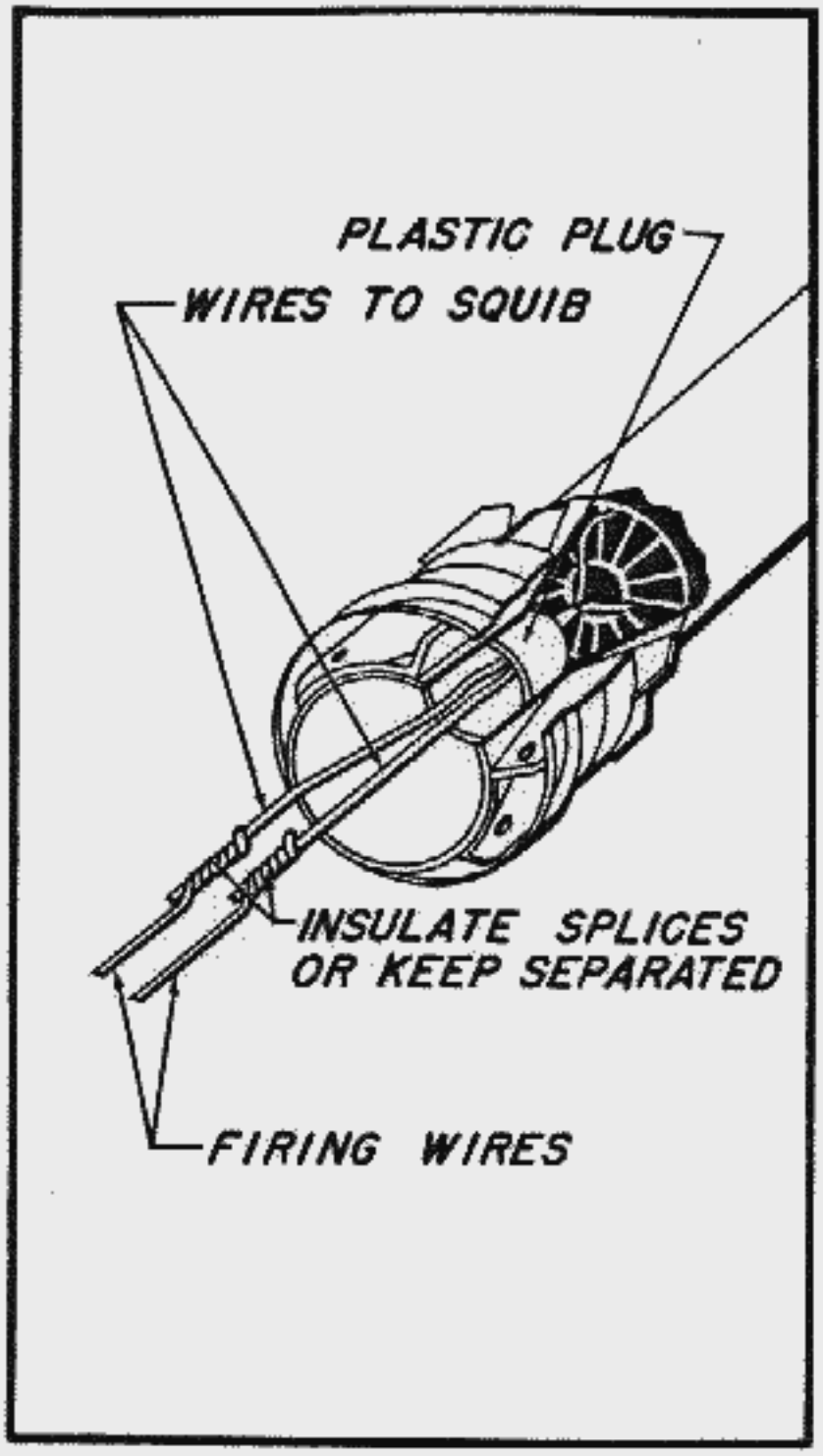


Fig. 56 — Electric Firing

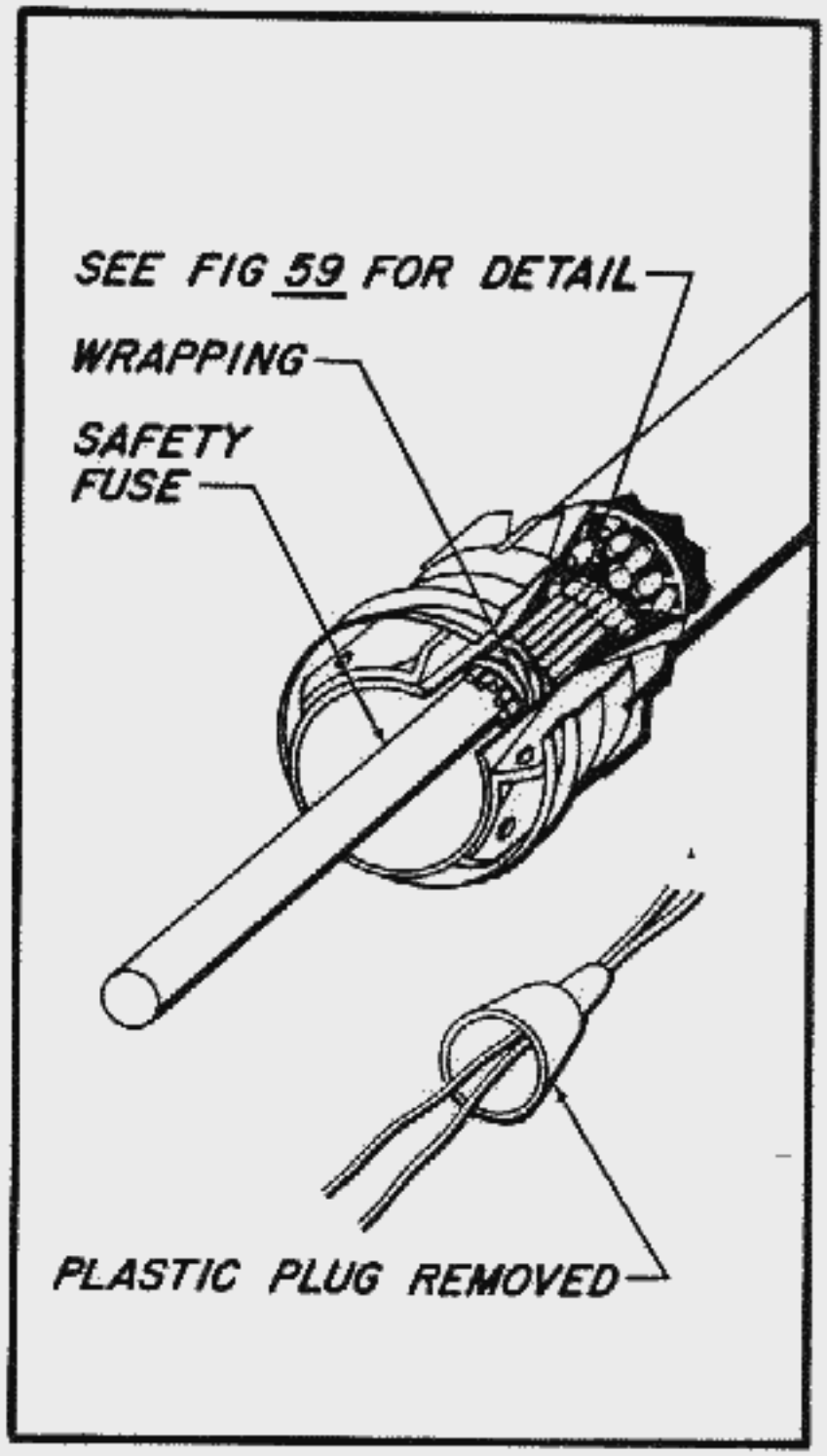


Fig. 57 — Nonelectric Firing

vent tube by prying loose with the pointed handle of crimpers.

2. Break off at least 20 safety match heads and drop them down into the cavity beyond where the plastic plug was removed.

3. Prepare a time fuse fire starter as described and illustrated in the following section on "improvised incendiaries." See Figure 59. Insert the fire starter among the match heads and wedge it securely in position with paper, tape, or parts of a match box. See Figure 57.

4. The rocket can now be fired from an improvised launcher by lighting the time fuse.

ALTERNATIVES: A spoonful of match head igniter (match head scrapings) can be used in place of the 20 match heads. A magnesium head time pencil, or a time pencil to which is attached a small sack or paper tube loosely filled with black powder, can be substituted for the match heads and the time fuse fire starter.

Ranges and Aiming

The minimum range for the 3.5 rocket is 15 feet, which is the distance required for the bore-riding safety to fly free and arm the rocket. The best point blank range is 15 feet to 100 feet.

Because removal of the plastic plug lowers the initial pressure, the range of the rocket when fired nonelectrically will be a little reduced and aiming should be a little higher.

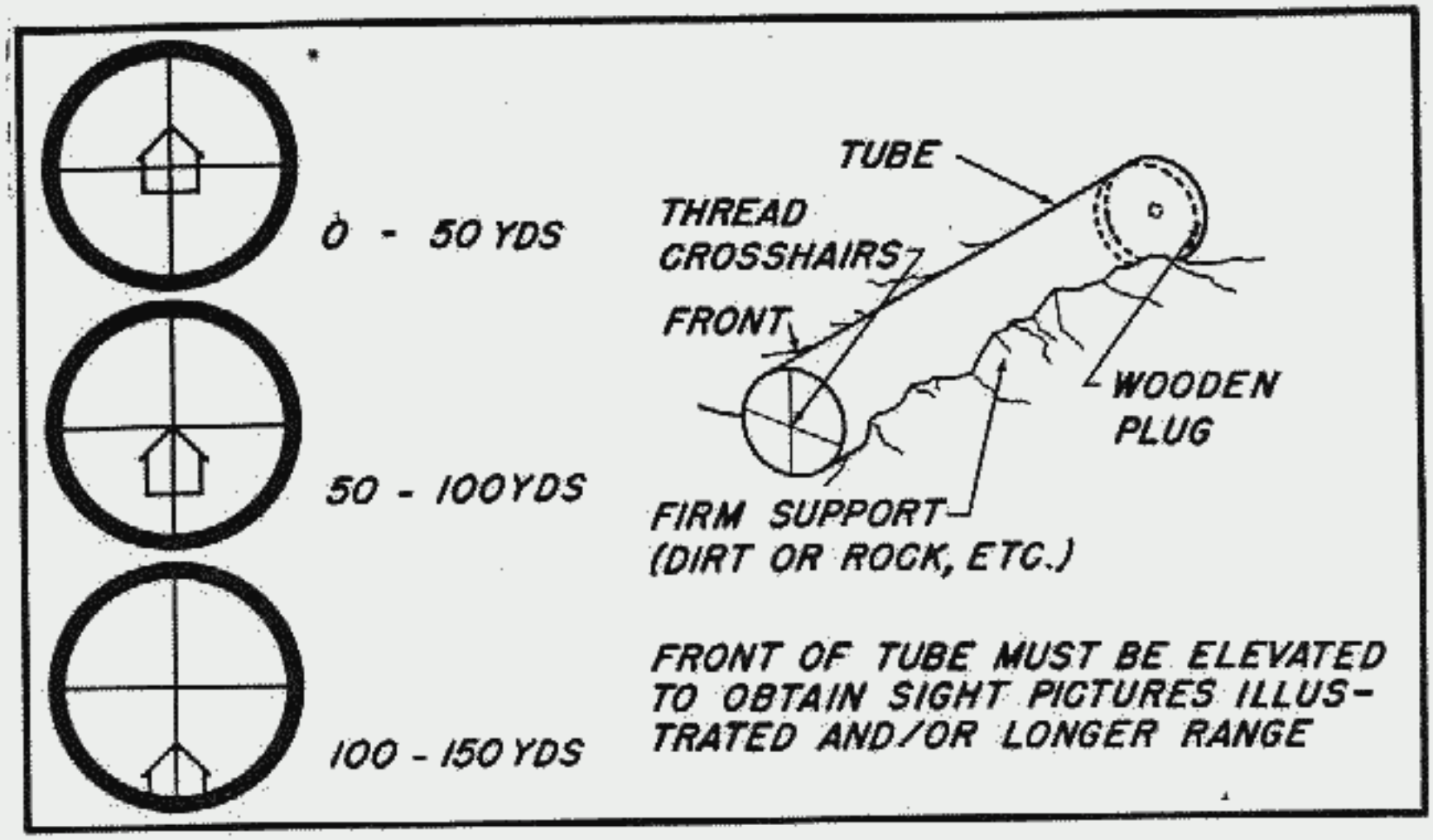

0 - 50 YDS
50 - 100YDS
100 - 150 YDS
TUBE
THREAD CROSSHAIRS
FRONT
WOODEN PLUG
FIRM SUPPORT (DIRT OR ROCK, ETC.)
FRONT OF TUBE MUST BE ELEVATED TO OBTAIN SIGHT PICTURES ILLUSTRATED AND/OR LONGER RANGE

Fig. 58 — Sighting of Rocket

With practice a high degree of accuracy can be obtained with improvised launching of the 3.5 rocket. The inner cardboard tube in which the rocket is packed makes an excellent launcher. Remove the staples which hold the wooden plug in the end of the tube so the plug can be easily removed and reinserted. Attach crosshairs of thread or other material to the front of the tube, as illustrated in Figure 58, and sight in on the target through the peephole in the wooden plug. When the tube is sighted in on the target, wedge the tube firmly in that position, remove the plug and insert the rocket from the rear.

Figure 58 illustrates points of aim for different distances.

IMPROVISED INCENDIARIES

General

Good incendiaries can be improvised more easily than explosives and the materials are more easily obtained. On a pound for pound basis, incendiaries can do more damage than explosives against many type targets if properly used. There is a time lag, however, between the start of a fire and the destruction of the target. During this period the fire may be discovered and controlled or put out. An explosive once detonated has done its work.

Incendiaries are cheap and little training is needed for their preparation and use. Used in very carefully executed operations, the act of sabotage may be concealed in the ashes of an "accidental" fire.

Fires may be started quickly and have reasonable chance of success if the following few simple principles are observed:

1. See that there is plenty of air and fuel to feed the fire.

2. Use an incendiary that supplies a prolonged and persistent heat.

3. Start the fire low in the target structure and let it spread naturally upwards.

4. Use reflecting surfaces, such as corners, boxes, shelves, to concentrate the heat.

5. Use drafts to spread the fire rapidly -- near stairways, elevator shafts.

6. Protect the fire from discovery during the first few minutes by good concealment and timing.

In preparing improvised incendiaries observe basic rules of safety. Chemicals that must be powdered should be ground separately with clean tools and then mixed in the indicated proportions. Chemicals or mixtures should be kept tightly sealed in jars or cans to protect them from moisture. Damp materials will work poorly if at all.

Sulfuric acid, which is useful for chemical delays and to ignite incendiaries or explosive detonators, can be obtained by concentrating battery acid. This can be done by boiling off the water in the battery acid in a glass or porcelained pan until dense white fumes begin to appear. This operation should be done out of doors and the resulting concentrated acid should be handled carefully.

The paragraphs which follow will describe the preparation of several igniter (or "first fire") incendiary mixes, some basic incendiary mixes, and a thermate metal-destroying incendiary.

The subject of incendiaries has been treated much more exhaustively in other publications. The intent of this handbook is to provide only a few techniques.

Potassium Chlorate and Sugar Igniter

Chlorate-sugar is one of the best of the first fire or igniter mixes. It burns very rapidly, with a yellow-white flame, and generates sufficient heat to ignite all homemade incendiaries mentioned in this handbook.

MATERIALS: Potassium chlorate (preferred) or sodium chlorate, sugar.

PREPARATION:

1. Grind the chlorate separately in a clean, non-sparking (glass or wooden) bowl with a wooden pestle. The resulting granules should approximate those of ordinary table sugar.

2. Mix equal volumes of the granulated chlorate and sugar by placing both on a large sheet of paper and then lifting the corners alternately.

CAUTION: This mixture is extremely spark sensitive and must be handled accordingly.

3. Wrap 4 to 6 tablespoonfuls of the mixture in thin paper so as to form a tight packet.

Keep the mixture as dry as possible. If it is to be stored in a damp area before using, the packet may be coated with paraffin wax.

Chlorate-sugar is easily ignited by the flame of a match, the spit of a percussion cap or time fuse, the heat of an incandescent wire, or upon contact with concentrated sulfuric acid.

If ignited when under confinement, it will explode like gunpowder. If it is contained in a waxed packet, therefore, the latter should be punched through in several places before it is used with a basic incendiary and ignited.

Flake Aluminum-Sulfur Igniter

This simple igniter burns extremely hot and will ignite even the metal-destroying thermate described later on. The mixture itself can be lit by chlorate-sugar.

MATERIALS: Flake aluminum, finely powdered sulfur.

PREPARATION:

1. Mix 4 parts by volume of finely powdered sulfur with 1 part of aluminum powder.

2. Stir or shake in a closed container until the powders are thoroughly mixed and no lumps of sulfur remain.

To use, place several spoonfuls of the mixture on the material to be lit and add a spoonful of chlorate-sugar on top. Be sure the safety (time) fuse or other spark-producing delay system is placed so it will act upon the chlorate-sugar mixture first.

Homemade Black Powder Igniter

Black powder may be used for igniting napalm, flammable solvents in open containers, paper, loose rags, straw, excelsior and other tinder type materials. If it is not available already mixed, it can be prepared as follows:

MATERIALS: Potassium (or sodium) nitrate, powdered sulfur, powdered charcoal.

PREPARATION:

1. Into a clean, dry jar or can put 7 spoonfuls of potassium or sodium nitrate, 2 spoonfuls of powdered charcoal, and 1 spoonful of powdered sulfur. The ingredients must be at least as fine as granulated sugar. If they must be ground, GRIND EACH SEPARATELY. Never grind the mixed ingredients -- they may ignite or explode.

2. Cap the can or jar tightly and shake and tumble it until the ingredients are completely mixed.

The mixture will be effective for months if kept tightly sealed and dry. Sodium nitrate in particular has a tendency to absorb moisture.

To use the gunpowder, pile 2 or 3 spoonfuls on top of any solid incendiary material which is to be ignited. For igniting liquids in open containers, wrap 2 or 3 spoonfuls in a piece of paper and suspend it just above the liquid.

Gunpowder is best ignited by safety fuse. It burns very quickly and with a great deal of heat, so allow sufficient time delay for safe withdrawal from the vicinity. -

Match Head Igniter

A good ignition material for incendiaries can be obtained from the heads of safety matches, which are available almost any place. The composition must be removed from the heads of many of them to get a sufficient quantity of igniter material. It will ignite napalm, wax and sawdust, paper, and other flammables.

MATERIALS: Safety matches.

PREPARATION:

Remove the match head composition by scraping with a knife or crushing with pliers. Collect several spoonfuls of it and store in a moisture-tight container.

Put at least 2 spoonfuls on the material to be ignited. To ignite liquids, such as solvents or napalm, wrap several spoonfuls in a piece of paper and hang this just over the fluid, or place nearby. If fluids dampen the mixture it may not ignite.

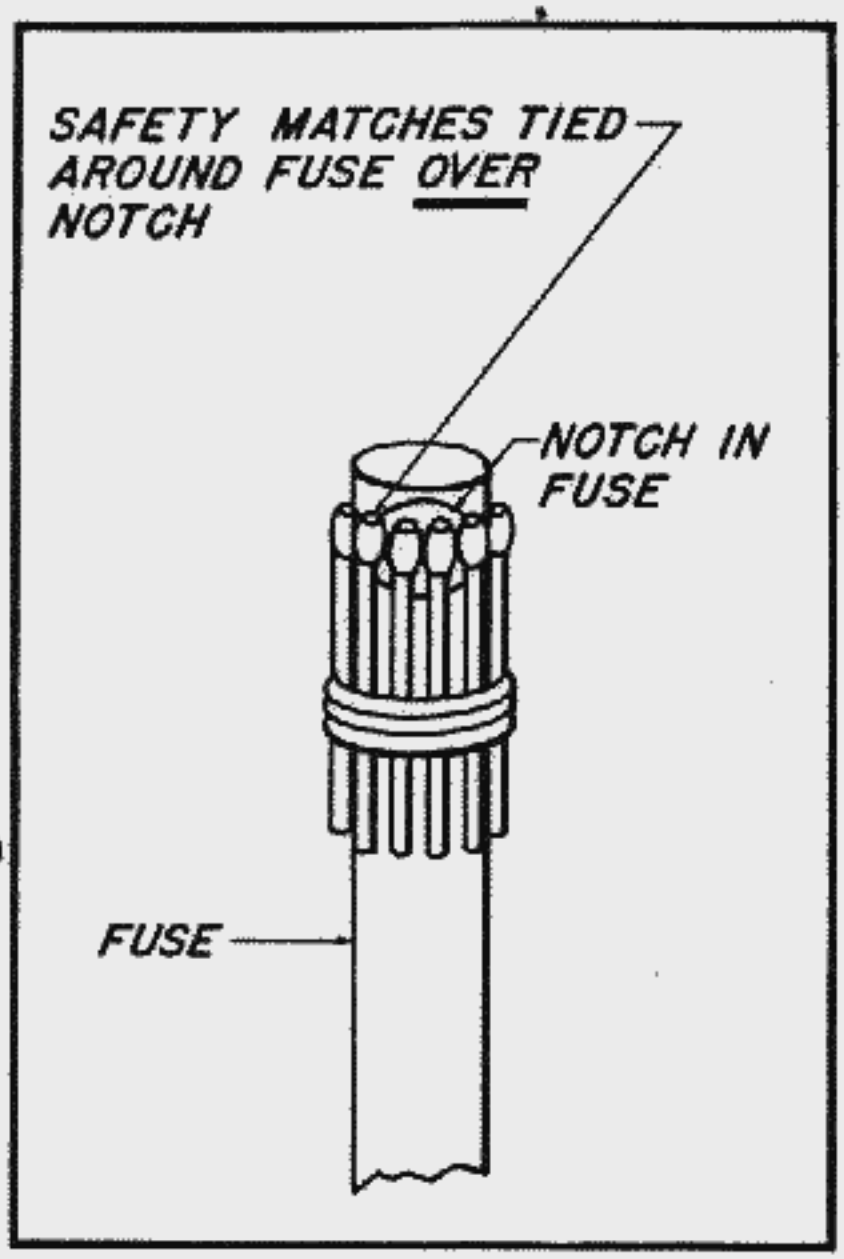


Fig. 59 — Time Fuse Fire Starter

Ignition can be by time fuse, firecracker fuse, a spark, or concentrated sulfuric acid.

Time Fuse Fire Starter

Several igniters or first fire mixes can be set off by a spark from time fuse. Others require a stronger flame. Time fuse, plus matches, can be combined to provide this more intense initial flame.

MATERIALS: Time (safety) fuse, safety matches, string or tape.

PREPARATION:

1. About 1/4 inch from the end of a piece of time fuse cut a notch with a sharp knife so that the powder train is exposed.

2. Around the fuse at this point tape or tie several matches so that their heads are in contact with each other and at least one match head is directly over the notch. See Figure 59.

When the fuse burns down, a spark from the notch ignites the one match head, which flares and ignites the others. This fire starter can be inserted into an igniter mix or used alone to light crumpled paper or excelsior. Another application, nonelectric firing of the 3.5" rocket, is described earlier.

Homemade Napalm

Napalm is the best incendiary to use against most flammable targets. It will readily ignite paper, straw, flammable solvents, or wooden structures.

MATERIALS: Gasoline or fuel oil, non-detergent soap (bar, flakes, or powder).

PREPARATION:

1. Use about equal parts of soap and oil. If bar soap is used, slice it into small chips. If both gasoline and fuel oil are available, use both in equal parts.

2. Heat the fuel in an open container, preferably one with a handle OUT OF DOORS. Try to avoid creating sparks or having a high open flame, but if the fuel should catch on fire, extinguish it by placing a board or piece of tin over the container.

3. Gasoline, in particular, will begin to bubble very quickly. When it does, remove

Fig. 60 — Molotov Cocktail

from the fire and gradually add the soap, stirring continuously, until the soap is completely dissolved and a thin pasty liquid results. If necessary return the mixture to the fire, but as a safety measure it is best not to stir while the container is on the fire.

4. When the desired consistency is reached allow the mixture to cool.

5. Napalm also can be mixed by a cold method, although it may take hours to thicken. This should be done by alternately adding very small amounts of soap chips or powder and gasoline or fuel oil and stirring until the mixture reaches a thin jelly-like consistency. It is best to start with about a cupful of soap, add part of a cup of solvent and stir that until smooth before gradually adding the remaining ingredients. Continuous stirring is not required. In fact, it is advisable just to let the mixture and the mixer rest from time to time and give the soap a chance to dissolve.

Napalm will keep well if stored in a tightly sealed container. It can be ignited with a match or any of the first fire mixtures described previously. The ignition packet should be placed adjacent to or just over the napalm, otherwise the petroleum may soak it and prevent its burning.

When napalm is used on easily ignitable materials (such as loosely piled paper, rags, or hay) it should be spread out so it will start a large area burning at once. Tightly baled paper or rags should be loosened first, because they do not burn well. If used directly against wooden structures or other large articles which are difficult to ignite, the napalm should be concentrated in sufficient quantity to provide a hot, long lasting blaze. If about a half dozen pieces of charcoal are put into and around the napalm the heat output is considerably increased.

Napalm makes an excellent "Molotov Cocktail." Just fill any glass bottle with a small neck with the napalm and cram a twisted strip of cloth into the mouth of the bottle as a stopper. See Figure 60. When ready to use, pull about 4 to 6 inches of the rag stopper out of the bottle. Light the napalm-soaked rag with a match and, when the rag is burning well, throw the bottle at the target. When the bottle breaks napalm splashes over the target and is ignited by the burning rag.

Paraffin-Sawdust Incendiary

Paraffin-sawdust is almost as effective as napalm against combustible targets, but it is slower in starting. It is solid when cool and thus is more easily carried and used than liquid napalm. In addition, it can be stored indefinitely without special care.

MATERIALS: Dry sawdust, paraffin, beeswax, or candle wax.

PREPARATION:

1. Melt the wax, remove the container from the fire and stir in a roughly equal amount of sawdust.

2. Continue to stir the cooling mixture until it becomes almost solid, then remove from the container and let it cool and solidify further.

Lumps of the mixture the size of a fist are easiest to manage. The chunks of incendiary may be carried to the target in a paper bag or other wrapper. Any igniter that will set fire to the paper wrapper will ignite the wax and sawdust.

A similar incendiary can be made by dipping sheets of newspaper into melted wax and allowing them to cool. These papers may then be crumpled up and used in the same manner as the paraffin-sawdust, although they will not burn as hot and persistently.

Sawdust, Moth Flakes, and Oil Incendiary

This incendiary is very good for use against all kinds of wooden structures, including heavy beams and timbers. It also works well on paper, rags, straw, excelsior, and other tinder type materials. It will start fires in open containers of flammable liquids, piles of coal, coke, or lumber, and on baled rags and paper. It is not effective against metal.

MATERIALS: Dry sawdust, moth flakes (naphthalene), fuel oil (kerosene or diesel oil).

PREPARATION:

1. Place equal parts of sawdust, moth flakes, and oil into a container and stir until the mixture is the consistency of mush.

2. Store it in any container that will retain the oil fumes.

An easy, effective way to use this mixture is to put about a quart of it in a paper bag and place the bag on the target material. The bag can be lit with a match and the mixture will ignite quite readily. It burns as well as napalm. If a longer delay time is required, use one of the igniter mixes described earlier along with time fuse or other delay device. The time fuse alone, however, will not ignite the incendiary mix.

Where very large wood beams are to be burned, an additional amount of the incendiary will be required. Two or three quarts is enough to destroy almost any target against which the technique would be effective.

For the greatest effect on wooden structures, the mixture should be in a pile, never spread out in a thin layer. It should be placed beneath the target material, if possible, so the flames will spread upward. In a packing box or room, a corner is a good place to start the fire.

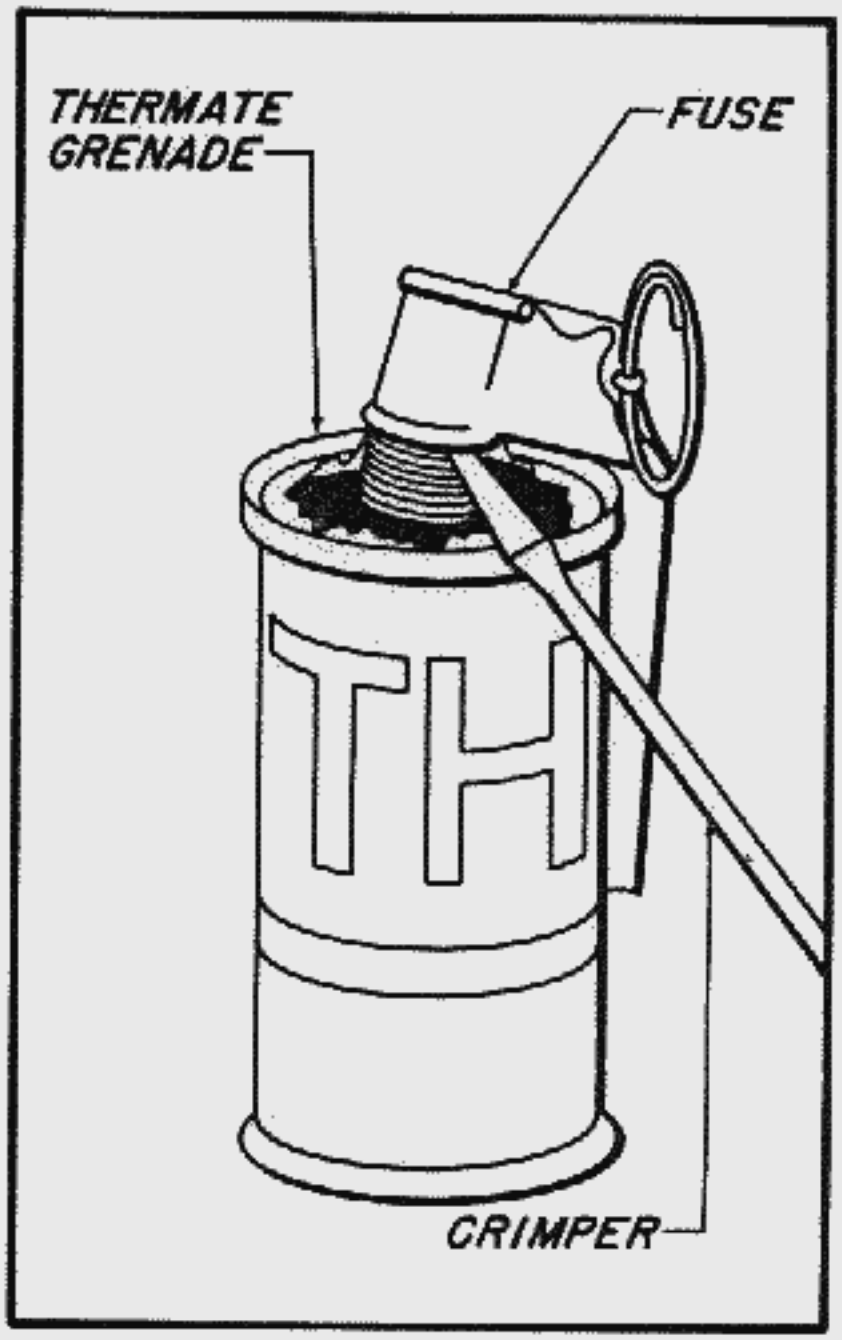


Fig. 61 — Defusing Thermate Grenade

Thermate Incendiary

Thermate is similar to commercial thermit, used in welding, except that it also contains an oxidizer, making it easier to ignite. Thermate will readily burn paper, rags, excelsior, straw, and other tinder type materials. However, its main use in sabotage operations is against motors, gears, lathes, or other metal targets -- to weld moving parts together, warp precision machined surfaces, and so on. Since it burns with a brief, almost explosive action, it is not recommended for burning wooden structures or other materials where persistent heat is required.

A good source of ready-made thermate is the U.S. military AN M-14 Incendiary Grenade. To remove the thermate, first pry out the fuse assembly with crimpers or other nonsparking implement. See Figure 61. The reddish-brown caked substance on top of the contents of the grenade is a first fire mixture and it is spark sensitive. This should be broken up and the grayish powder beneath, which is the thermate, can be poured out.

Thermate also can be made from aluminum or magnesium powder and a chemical oxidizing agent, as described below:

MATERIALS: Aluminum filings, powder or flakes, or magnesium filings or powder, plus any one of the following chemicals: potassium nitrate, sodium nitrate, barium nitrate, potassium dichromate, sodium dichromate, or potassium permanganate. Although aluminum and magnesium are equally effective, thermate made from magnesium is easier to ignite. Flake aluminum, which is the extremely fine variety used in paints, is excellent. In any case, both the metal and chemical ingredients should be no coarser than granulated sugar.

PREPARATION:

1. Fill a quart size (or larger) container about 2/3 full of equal parts of the metal powder and the oxidizing agent.

2. Cover with a tight lid, then roll and tumble the container until the contents are completely mixed.

3. If FLAKE aluminum is the metal used, fill the container 1/2 full of the aluminum, then add oxidizing agent until the container is 3/4 full. Mix as described above.

Thermate in a sealed container can be stored for months. To use, put 1 or 2 pounds of the mixture in a paper bag and place it on the target in such a way that when it burns the red hot molten material will run down and attack the vital parts.

Chlorate-sugar and aluminum-sulfur igniters are best for setting off thermate, particularly if the thermate contains aluminum powder, which is more difficult to ignite.

Thermate also is used in the improvised dust initiator and the external POL charges described later.

DUST AND VAPOR EXPLOSIONS

General

A dust or vapor explosion sometimes happens accidentally in industries, causing great damage. Several readily available materials are explosive when mixed with air in the form of a dust or vapor, so such explosions can be induced as a sabotage technique. Among suitable materials are flour, cornstarch, powdered milk, cocoa, very fine aluminum or magnesium powder, gasoline, and fuel oil.

To cause an explosion with any of these materials, it is necessary to scatter them through the air as vapor or dust and then ignite them. A device that can be made to do this is called a dust initiator. It is a small charge of explosive mixed with incendiary material. When detonated within or under a container of the dust or vapor material it will break the container, scatter the material through the air and then ignite the particles to create a second explosion.

The damage is greatest in a completely enclosed space since the destructive effect is due to the pressure of expanding gas pushing out walls and collapsing the building. Buildings with many windows or other large openings may not be badly damaged.

Very frequently an incendiary effect follows the explosion, setting fire to the debris, especially if gasoline, oil, or metals are used as the secondary explosion material.

High humidity or damp or wet materials will weaken the explosive effect of a dust initiator, even causing a complete failure.

Although it is not possible to estimate precisely the amount of dust or vapor producing material needed for a given target, too much or too little will decrease the effect. Experience has shown that for each 1,000 cubic feet volume of the target building you should use about 1-1/4 pounds of flour, cornstarch, etc., or 4/5 gallon of gasoline or kerosene. The initiating charge itself (explosive and incendiary) should be between 1 to 2 pounds to scatter and ignite 25 pounds of dry dust or 5 gallons of liquid fuel.

Improvised Dust Initiator

The dust initiator is a small explosive/incendiary charge which can be used to initiate dust or vapor explosions in closed areas such as buildings, rooms, boxcars, or closed storage areas.

MATERIALS: Explosive, thermate, blasting cap, and secondary material: flour, cornstarch, powdered milk, cocoa, gasoline or other volatile fuel.

PREPARATION:

1. Mix equal parts of explosive and thermate incendiary. A powdered explosive is easiest to use, and TNT may be safely curshed with a wooden implement in a wooden container. Plastic explosive or dynamite also may be used, although in this case the explosive should be placed under the thermate so that the thermate will be directed upward. The thermate can be obtained from the AN M-14 incendiary grenade or homemade as

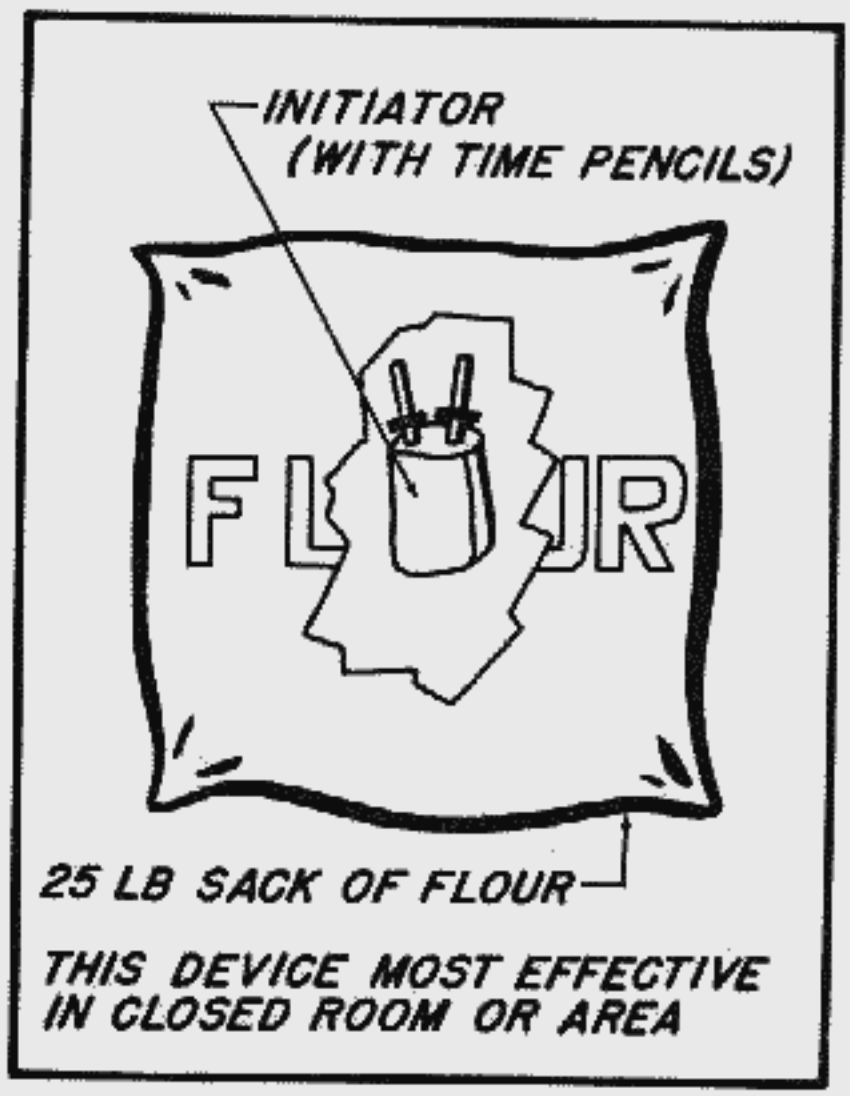


Fig. 62 — Dust Initiator

described in the section on "improvised incendiaries."

2. If a dust or powder is to be used for the secondary explosion, the explosive/incendiary initiator may be enclosed in any sort of a packet and placed within or under the material to be dispersed and ignited. See Figure 62. If the initiator is to be used in gasoline or fuel it will have to be enclosed in a fuel-tight bottle and sealed with some material impervious to petroleum solvents. An alternative is to put the initiator under the container of fuel rather than in it. In all cases, the initiator should be beneath or within the material to be dispersed rather than on top of it. The best placement is in the center of the target area and at least a foot above floor level. If the charge is placed in a basement, the pressures will be confined and directed upward, increasing the total damage.

The charge may be detonated either electrically or nonelectrically by a blasting cap placed within the explosive/incendiary initiator. Any one of several of the delay systems previously described may be employed.

POL CHARGES

Internal Flotation Charge

This charge combines explosive and incendiary material arranged in a container which will float on the surface when dropped into a large POL storage tank. The advantage of using an internal charge is that the charge need not be as large as one placed externally. Also, being inside the tank the charge is concealed and in less danger of discovery if a long term delay is desirable. On the other hand, an external charge is less complicated to make and easier to place since it doesn't require access to the maintenance and inspection hole in the roof of the tank.

MATERIALS: Fuel-tight container (approximately 2 gallon volume), plastic explosive, thermate, primacord, nonelectric blasting cap, delay device.

PREPARATION:

1. Cut a piece of primacord about 12 inches long. Tie a triple roll knot in one end and a girth hitch or other tight knot a few inches above the end knot.

2. Pack about 2 pounds of plastic explosive tightly into the bottom of the container and imbed the triple roll knot in it.

3. Add about the same quantity of thermate on top of the explosive. The thermate may be that obtained from the AN M-14 incendiary grenade or homemade, as described in the section on "improvised incendiaries." A coarse grain thermate (coffee ground size or larger) will work better in this technique than powdered thermate, and magnesium is preferable to aluminum.

4. Add another layer of plastic explosive equal to the bottom layer and be sure the girth hitch knot is imbedded in this layer. The sandwiched layers of explosive and thermate should occupy no more than the bottom two-thirds of the container, the rest being open air space to provide buoyancy of the charge (in fuel oil or gasoline, not water) prior to placement in the target. If additional buoyancy is needed, a block of wood can be added in the top of the container.

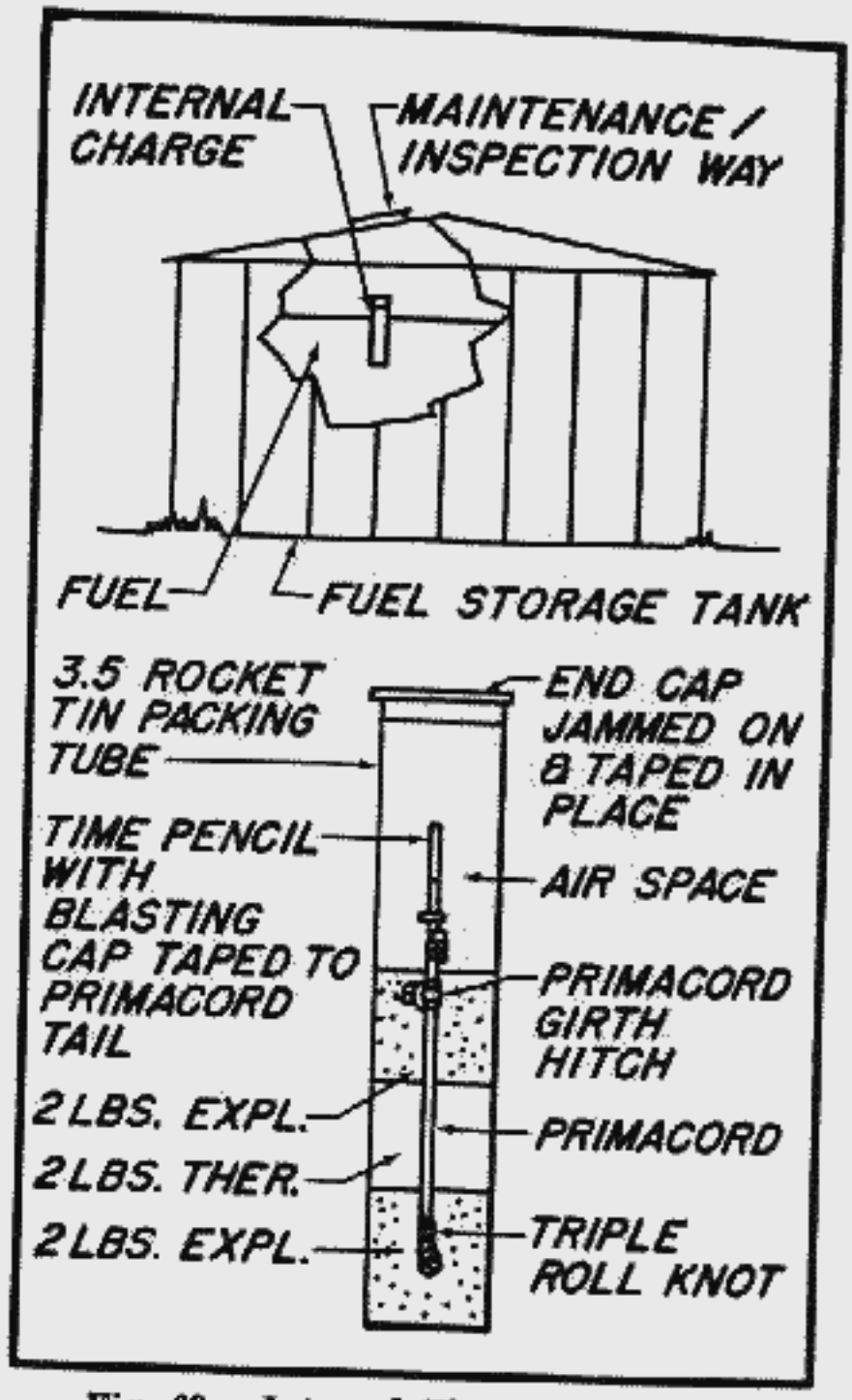


Fig. 63 — Internal Flotation Charge

Figure 63 shows the makeup of the internal flotation charge and the final preparations necessary for priming. To prime, attach the blasting cap with a time pencil or other delay device to the top end of the primacord, initiate the delay and seal in the whole charge and firing system with an airtight cap. The charge can then be dropped into the tank and should float upright until the delay time expires and the charge is fired.

External Charge

A plastic soap box, a cigar box or any such container can be used to fashion a simple charge for attacking fuel tanks from the outside. The soap box size charge is large

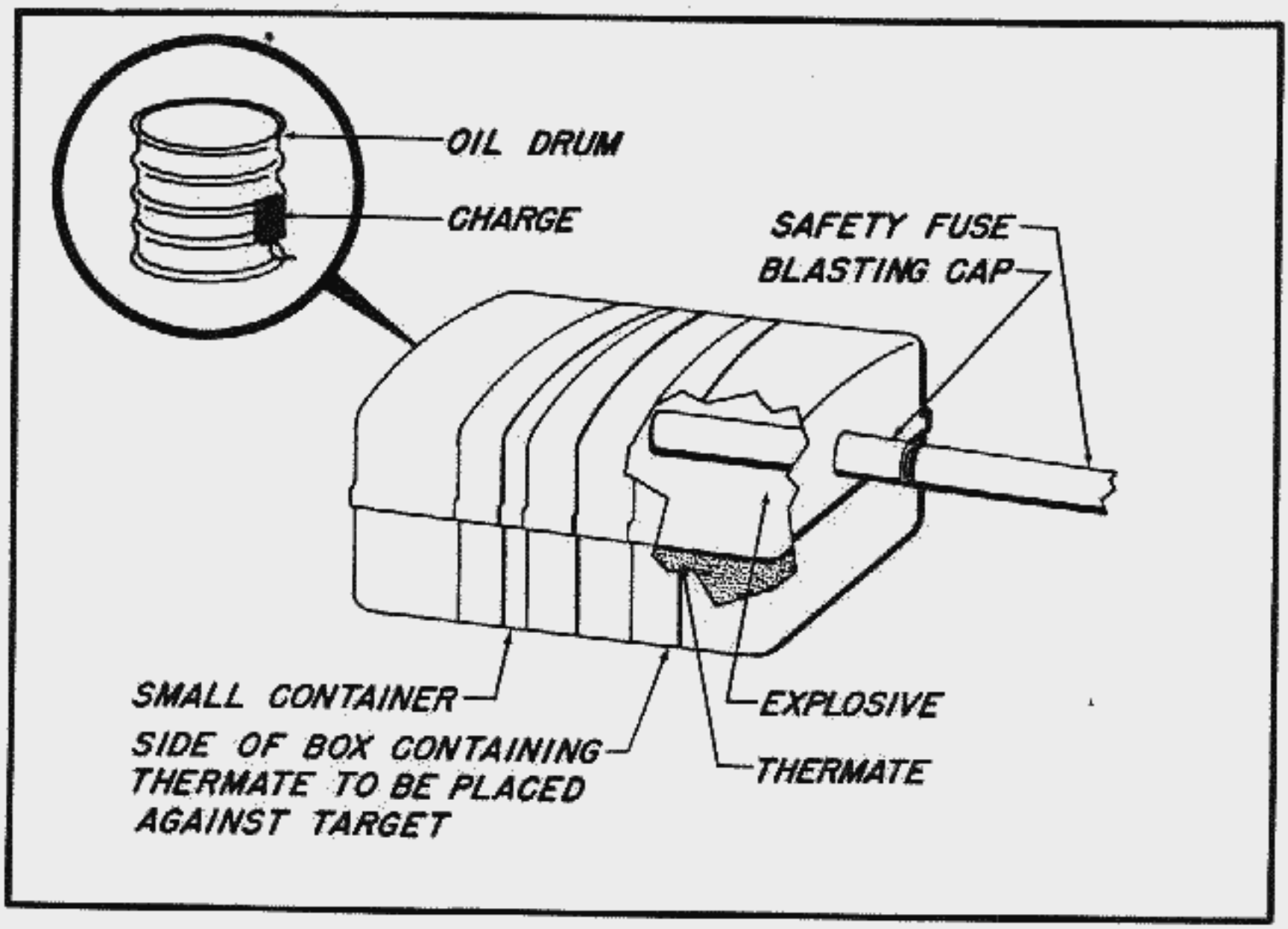


Fig. 64 — Soap Box Charge

enough for vehicle gas tanks or 55 gallon drums, while the cigar box size will handle storage tanks from 55 to 10,000 gallons capacity.

MATERIALS: Container, thermate, plastic explosive, nonelectric blasting cap, safety fuse, primacord (optional).

PREPARATION:

1. Fill the container half full of coarse thermate (obtained from the AN M-14 incendiary grenade or homemade).

2. On top of the thermate tightly pack an equal amount of plastic explosive, completely filling the container.

Prime the charge either with a triple roll primacord knot or a nonelectric blasting cap. Figures 64 and 65 illustrate properly made up charges.

The charge must always be placed so that the thermate side is against the target, otherwise the thermate would be blown away from the target when the charge explodes.

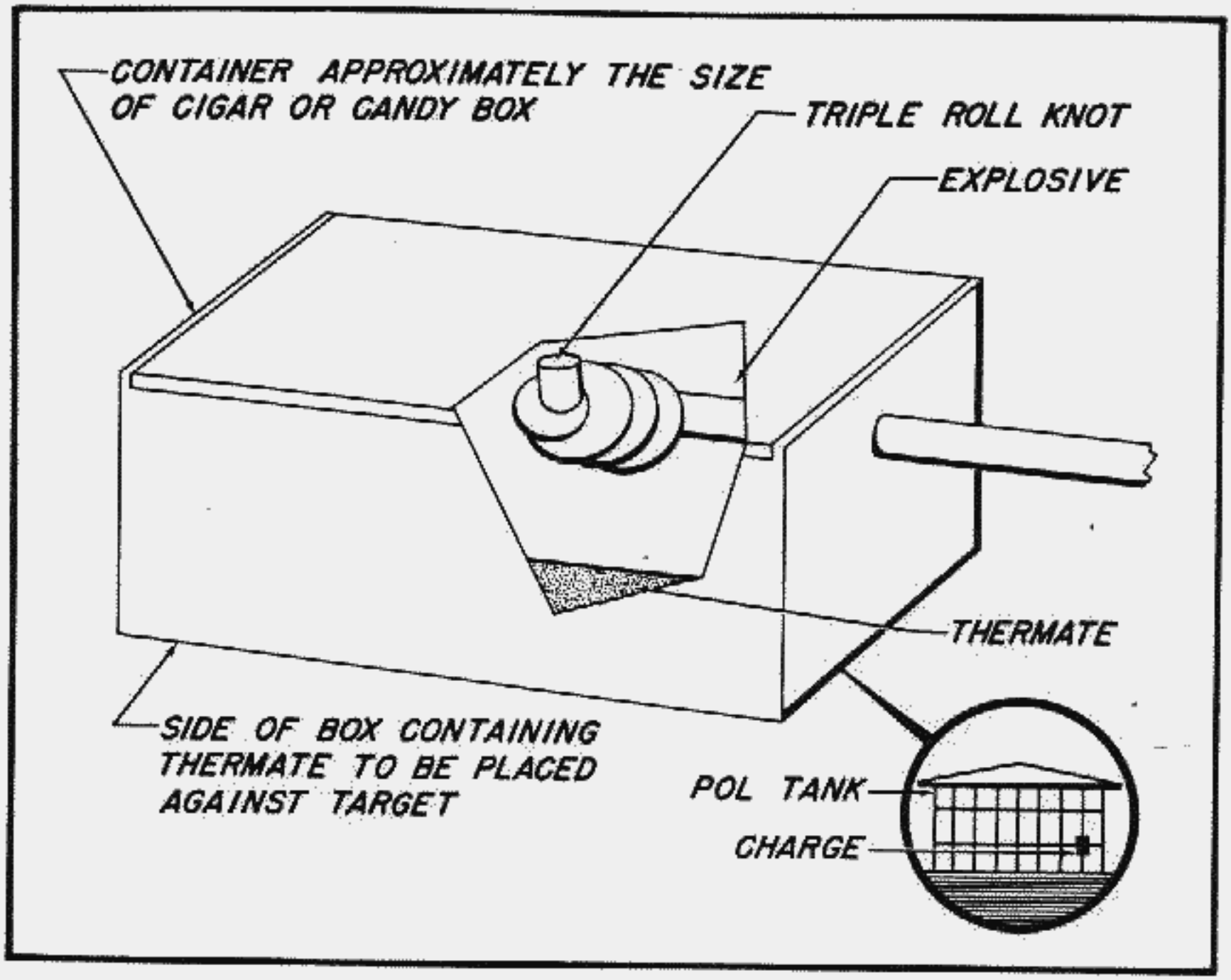


Fig. 65 — Cigar Box Charge

TARGET SUMMARY

Since many of the improvised devices and techniques described in the preceding sections of this handbook are applicable against a variety of targets, it seemed more feasible to organize the contents on a techniques rather than a target basis.

In summary, however, it might be helpful to review potential targets and list the techniques which could be used against them.

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MCRP 3-37C
FM 3-11

Flame, Riot Control Agents and Herbicide Operations

U.S. Marine Corps

PCN 144 000012 00

Preface

This publication describes the doctrine, tactics, and techniques for employing flame weapons, riot control agents (RCA), and herbicides during peacetime and combat. It is intended primarily for use by chemical personnel at all echelons in planning the employment of flame and non-lethal materials (RCAs and herbicides). Training with RCAs is discussed in detail in TC 3-8, *Chemical Training*.

This manual does not implement any international standardization agreements; however, the material within the manual is in accordance with related international agreements.

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

Extracts from FM 5-250, *Explosives and Demolitions*, are used extensively throughout this field manual for technical and operational clarity. For further information concerning the use of military explosives and their components, see FM 5-250.

The proponent of this publication is the US Army Chemical School. Send comments and recommendations on DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to:

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CHAPTER 1

U.S. Policy for Flame, Riot Control Agents and Herbicides

Policy govering US policy for RCA and herbicides is found in Executive Order 11850 dated 8 Apr 75, Renunciation of Certain Uses in War of Chemicals, Herbicides, and Riot Control Agents.

WARTIME USE

The US has renounced first use of herbicides in war except under regulations applicable to domestic use or for control of vegetation within US bases and installations and around their immediate perimeters.

The US has renounced the first use of RCAs in war. US forces will only use RCAs in war in defensive modes to save lives as approved by the President.

In wartime, use of RCAs outside the war zone is authorized as prescribed for peacetime.

For RCA and herbicide use, war is any period of armed conflict no matter how it may be characterized, including declared and undeclared war, counterinsurgency, and any other uses of armed forces in engagements between US military forces and foreign military or paramilitary forces. Armed conflict is conflict between states in which at least one party has resorted to the use of armed force to achieve its aims. It also may involve conflict between a state and uniformed or non-uniformed groups within that state, such as organized resistance groups.

Commanders must recognize that, while the US does not consider herbicides and riot control agents to be chemical weapons, some other countries do not draw a distinction. Commanders must consider international ramifications and Rules of Engagement before recommending the use of herbicides or RCAs.

PEACETIME USE

The Secretary of the Army, as Executive Agent for the Department of Defense for civil disturbance operations, has issued instructions governing the use of RCAs in civil disturbances in the US, the Commonwealth of Puerto Rico, and US possessions and territories.

RCAs may be used on US bases, posts, embassy grounds, and installations for protection and security purposes, riot control, installation security, and evacuation of US noncombatants and foreign nationals. The US-controlled portions of foreign installations are considered US installations.

Chemical aerosol-irritant projectors may be used by military law enforcement personnel for the performance of law enforcement activities. They may be used--

- On-base and off-base in the United States and its territories and possessions.
- On-base overseas and off-base overseas in those countries where such use is specifically authorized by the host-country government.

RCAs may be used off-base (worldwide) for the protection or recovery of nuclear weapons under the same conditions as those authorized for the use of lethal force. (See DOD Directive 5210.56.)

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Peacetime Use

Authority

Weapons Employing Fire

RCAs may be used in training. A review of current treaties and/or Status-of-Forces Agreements between the host country and US forces may be required in determining whether or not training with RCAs is authorized overseas.

Herbicides may be used within US bases, posts, and installations for control of vegetation. Use of herbicides off-base overseas must be in accordance with host country laws and agreements, US Environmental Protection Agency (EPA) requirements, or Service regulations, whichever are the most stringent.

AUTHORITY

Only the *President* may authorize the following:

- Use of RCAs in war, including defensive military modes. However, advance authority to use RCAs for protection or recovery of nuclear weapons has been delegated to the Secretary of the Defense.
- Wartime use of herbicides, including installation vegetation control.

The *Secretary of Defense* may authorize the following:

- Use of RCAs or herbicides in peacetime.
- Use of RCAs in wartime for the protection or recovery of nuclear weapons.

CINCs and the Chiefs of Services may authorize:

- The use of RCAs in peacetime on US installations for riot control, installation security, civil disturbance operations, and non-combatant emergency evacuation operations. The US-controlled portions of foreign installations are considered US installations.
- The movement and storage of RCAs and herbicides, as necessary, to support requirements, provided US control is maintained.
- The off-base use of RCAs in peacetime for the protection or recovery of nuclear weapons under the same situations as authorized for the use of lethal force.
- The use of herbicides in peacetime within and, when authorized by the host country government, around US bases for control of vegetation.
- The use of chemical aerosol-irritant projectors by military law enforcement personnel during peacetime for the performance of law enforcement activities in the following areas:
    - On-base and off-base in the US and its territories and possessions.
    - On-base and off-base overseas in those countries where such use is specifically authorized by the host country government.
- Authority for use of RCAs in peacetime situations not covered by the above (for example, to save lives in counterterrorist operations) will be addressed in plans and requested by the combatant commanders for Secretary of Defense approval.

WEAPONS EMPLOYING FIRE

The use of weapons that employ fire, such as tracer ammunition, flamethrowers, napalm, and other incendiary agents, against targets requiring their use is not a violation of international law. They should not, however, be employed to cause unnecessary suffering to individuals.

CHAPTER 2

Flame Operations

FLAME EFFECTS

Flame is a valuable close combat weapon that burns, depletes oxygen, and impacts psychologically. Since man fears flame, it is used to demoralize troops and reduce positions that have resisted other forms of attack. Flame produces the following effects:

Casualties. Casualties result from--

- Burns. Thickened fuel sticks to clothing and skin, burns with intense heat, and is extremely difficult to extinguish.
- Inhalation of flame, hot gases, and carbon monoxide.
- Suffocation.
- Shock.

Psychological. The psychological impact is probably one of the greatest effects of flame. In many cases, defending personnel will leave well-prepared positions and risk exposure to other weapons or capture. In other cases, the enemy is forced to withdraw from firing positions during the effective period of the flame attack. This permits friendly forces to close in before the enemy reoccupies his firing positions.

Splatter. Flame reaches around corners through the splattering and ricochet action of the thickened fuel on adjacent surfaces. The splattering action of the thickened fuel spreads the flame over an area--in contrast to the point effects of nonfragmenting small arms ammunition.

Incendiary. Flame ignites combustible materials to cause additional problems for personnel. Flame weapons ignite clothing, tentage, wires, petroleum products, buildings of light construction, light vegetation, munitions, and other combustible material.

Battlefield Illumination and Signaling. Controlled, slower burning flame field expedients (FFEs) can be used for close-in battlefield illumination and signaling. These devices can be made to vary in illumination time from a few minutes to hours.

Smoke. The burning fuel from flame weapons and FFEs produces a dense black smoke that can reduce battlefield visibility appreciably. Smoke from ignited materials can prolong this condition. This black smoke may attract the enemy's attention to the flame attack and invite counterfire. To minimize any hindrance to friendly operations, the

presence of this smoke must be anticipated when planning operations in which flame weapons or FFEs will be used.

FLAME WEAPONS

The flame weapons available are the M202A1 rocket launcher, incendiary grenades, and FFEs.

M202A1
Rocket Launcher

The M202A1 Rocket Launcher (Figure 2-1) is a lightweight, individual rocket launcher aimed and fired on the right shoulder from the standing, kneeling, or prone position. The launcher is loaded with a clip (M74) which contains four rockets. It can fire one to four rockets semiautomatically at a rate of one rocket per second and can be reloaded with a new clip.

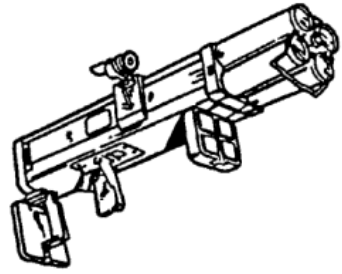

Figure 2-1. M202A1 flash, 66mm rocket launcher.

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The M74 rocket (Figure 2-2) is filled with thickened pyrophoric agent (TPA). This TPA is triethylaluminum (TEA), a substance similar to white phosphorus, which bums spontaneously when exposed to air (exposure occurs on impact, therefore, no fuel is wasted by burning en route to target). It burns at temperatures between 1400-2200 degrees Fahrenheit. The M74 is used to engage area-type targets out to a range of 750 meters and point-type targets out to a range of 200 meters. The minimum safe firing distance to a target is 20 meters (M74 has a bursting radius of 20 meters; therefore, engaging targets closer than 20 meters may result in injury to friendly troops).

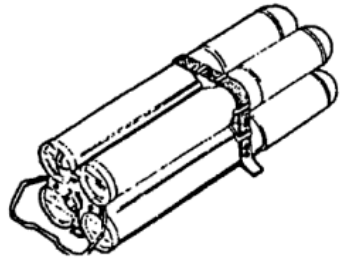

Figure 2-2. M74 rocket clips.

Incendiary Grenades

The AN-M14 TH3 incendiary hand grenade is filled with thermite, which bums at 4,000 degrees Fahrenheit. The grenade bums for 40 seconds and can bum through a 1/2-inch homogeneous steel plate. It can damage, immobilize, or destroy vehicles, weapon systems, shelters, or munitions. The grenade may also be used to start fires in areas containing combustible materials.

Flame Field Expedients

FFEs can generate violent, effective combat power at decisive times and places on the battlefield. These systems--fougasses, flame mines and flame trenches--can be used by tactical commanders to aid in--

- Repelling enemy penetrations.
- Destroying enemy forces.
- Gaining time.
- Providing obstacles.
- Isolating or canalizing an enemy.
- Slowing enemy movement.

- Surprising enemy forces.
- Degrading enemy morale.
- Deceiving enemy forces.

FFEs are formidable, uncomplicated weapons that lend themselves to support of both light and heavy forces at all levels of the spectrum of conflict. When applied at decisive times and places on the battlefield, flame weapons reinforce fighting positions, achieve surprise, and produce casualties and psychological shock. They may also provide battlefield illumination during limited visibility to help see enemy forces trying to assault friendly forces. Exploding FFE devices produce casualties from the immediate development of extremely high levels of heat at the moment of detonation. Additionally, exploding FFEs produce hundreds of white-hot shards of metal as the container breaks apart. However, the most dangerous part of an FFE is the burning thickened fuel that either is spread in all directions or projected over a large area. Thickened fuel is a syrupy liquid that sticks to a target and continues to burn. Once ignited, flame fuel is extremely difficult to extinguish.

Selected FFE devices are constructed to simply burn in place and provide light during limited visibility. Illuminating devices burn for an unspecified time. Generally, these flare-like systems will burn from four to eight hours depending upon the quantity of fuel contained. They are designed to provide battlefield illumination for the destruction of enemy forces trying to assault friendly fighting positions.

FLAME ATTACK TARGETS

In selecting flame attack targets, consider the type of flame weapon available.

Fortifications

Flame is particularly effective in the attack of personnel in shelters such as fortifications. Its effectiveness depends on as the size, number, and type of apertures and construction of the fortification. A small fortification may be entirely reduced, but a fortification with more than one internal compartment fortification with more than one internal compartment usually affords comparative safety to its occupants. The flame fuel must actually penetrate a fortification for maximum results. More fuel is required to cause casualties among personnel in well-ventilated fortifications than in poorly ventilated ones of the same size. Casualties in fortifications may result from suffocation (because oxygen from the air is consumed by the flame) or from actual burns.

Other Targets

Personnel in open fighting positions are vulnerable to flame. Thickened and pyrophoric fuel tends to stick to the clothing and skin of the occupants and the area, forcing the occupants to abandon the position or stay and be burned by the flaming fuel and risk becoming casualties.

Occupants of built-up areas can be forced to abandon their positions or become casualties, either from contact with the burning fuel or from fires caused by ignition of combustible materials (such as wooden buildings).

Personnel concealed in vegetation can be forced to abandon their positions or become casualties.

If the burning fuel penetrates the occupied compartment of the vehicles, personnel in armored vehicles may become casualties unless they abandon the vehicles. Armored vehicles buttoned up and moving are not good targets for flame. The burning fuel must penetrate the openings of the vehicles to be effective. Burning fuel will not ignite the tracks of moving armored vehicles. Incendiary devices attached to or penetrating the openings of armored vehicles can be effective in disabling the vehicles.

Personnel in unarmored vehicles will become casualties or be forced to abandon the vehicles if flaming fuel is placed in them, since any combustible material in or a part of the vehicles may be ignited or damaged.

Weapon positions may become untenable if hit with burning fuel or incendiary material. Occupants may become casualties and weapons and ammunition may be damaged.

Wires and cables covered with combustible material may be damaged by ignition of the coverings from burning flame fuel or fires from flame or incendiary devices.

Small arms ammunition may be destroyed by use of flame fuels and/or incendiary devices.

Generally, supplies that are combustible may be destroyed or damaged by flame fuels. Noncombustible supplies can be damaged or destroyed by incendiary devices or by secondary fires from combustible materials; for example, supplies stored in a wooden building would be damaged by fires that destroyed the building.

WEATHER EFFECTS ON FLAME FUELS AND WEAPONS

Wind has minimal effect on the M202A1's range and accuracy.

Rain has little effect on flame fuel in flight. Flame fuel will float and burn on water. The incendiary effect is less on damp material than on dry material.

Snow has little effect on flame fuel in flight. However, snow tends to smother flame, reducing its incendiary effects in the target area.

High temperatures tend to increase the fuel's incendiary action. Flame fuels in high temperatures may have to be thickened so that they do not burn excessively in flight to the target. Low temperatures decrease the incendiary action and more fuel may be required to ignite combustible materials. Additionally at low temperatures, flame fuel

may have to be made less thick to ensure ignition. Specific precautions and procedures must be followed in fuel selection, preparation, storage, and firing.

DESTRUCTION TO PREVENT ENEMY USE

Materiel subject to capture or abandonment in a combat zone (except medical) is destroyed by the using unit only when, in the judgement of the military commander concerned, destruction is necessary to keep the materiel from falling into enemy hands.

Emergency destruction procedures for fuel, ingredients, and flame weapons are given below. Detailed methods of equipment destruction are presented in appropriate technical manuals and bulletins pertaining to specific items of equipment.

Flammable fuels or lubricants may be destroyed by burning or pouring on the ground.

Thickeners may be destroyed by opening the containers and either dumping the contents into water or tire or spreading the contents on the ground. M202A1 rocket launchers and M74 rocket clips should be destroyed by burning, demolition, gunfire, or disposal.

FLAME EMPLOYMENT PRINCIPLES

Flame weapons are employed for both anti-personnel and anti-materiel effects. This principal use in offensive operations reduces fortifications, suppresses fire, and produces casualties or exposes enemy personnel to the fire of other weapons. In defensive operations they complement other weapons in fire plans. They can be used to destroy buildings and equipment, clear tunnels, destroy food, clear light vegetation, counter ambushes, illuminate defensive areas, warn of enemy approach, and restrict enemy use of trails and paths.

Tactics

Flame assumes great importance in ground warfare against an enemy whose tactics place emphasis on mass in the attack and stubborn, unyielding resistance in the defense. Even in relatively fluid, rapidly changing situations, an enemy may be able to establish excellent defensive fortifications, requiring increased use of flame for destruction.

The M202A1 and incendiary grenades are used primarily in offensive operations while FFEs are used primarily in the defense. The M202A1 can be used in both offensive and defensive roles because of its light weight, great range, and minimal service requirement. The decision to use M202A1, grenades, or FFEs is based on their comparative effectiveness for the particular mission.

In planning the attack, the commander considers the use of flame as a part of his fire support plan. Defensively, flame weapons may be used in the coordinated plan for fires and in support of the counterattack. Flame can often be used to blunt and disrupt mass enemy attacks, but the disadvantages of flame in both defensive and offensive operations

must be considered. Careful planning and coordination are needed for maximum benefit from the use of flame in the attack or defense.

OFFENSIVE FLAME USE

Flame has many qualifications as an offensive assault weapon. It demoralizes, produces casualties, and ignites combustible material; and it has good searching capability through its splattering action. When combined with infantry, tanks, and supporting fires, flame contributes greatly to the accomplishment of the mission. It is particularly effective when combined with infantry fires during the last stages of the assault. Flame weapons can be decisive against an enemy lacking any tank or fire support other than automatic weapons.

Plans should be as simple and direct as possible. Apply the following basic principles of employment in planning for the use of flame weapons in the attack.

As with other weapons, a proper reconnaissance is a must for successful employment of flame weapons. The target and any element supporting it must be located; a route of approach that offers protection from enemy fire must be selected; and the amount of flame required and the need for demolition and breaching support must be determined. The M202A1 can be employed without a thorough reconnaissance if the rear danger zone and the minimum safe range restrictions are observed.

Use sufficient flame. The number of flame weapons used depends on a number of factor--the size and nature of the objective, the terrain, and the enemies' morale and physical condition, for example. Piecemeal use of the M202A1 should be avoided. The enemy should be made to feel that unless he surrenders or withdraws immediately he will be burned to death. Within control capabilities for coordination of flame weapons supporting the maneuver force, the more flame that can be placed on suitable targets, the greater the probability of success during the attack. The attack should be pressed boldly. Supporting fires must lift or shift as necessary to allow flame weapons to close with the enemy. These fires should continue on enemy supporting positions.

Follow up with infantry. The enemy seldom fights at his best when he is caught in a flame attack. He usually does one of three things: surrenders, runs, or hides under cover. If he runs before the arrival of the flame, he may return to his position when the attack is over, even though the flame fuel is still burning on the ground. Enemy positions in the flame attack area may hold their fire until the flame attack is over. It is essential, therefore, that infantry supported by a flame attack follow it closely and quickly before the enemy can regain his position or reorganize his defenses. Friendly infantry must and can enter the area while flame is still burning on the ground. Troops must be given training in following a flame attack closely and in dashing through flame on the ground. Surprise and shock must be exploited to the fullest extent. Success in any tactical operation depends largely on the timing and coordination between the flame teams and the unit with which they are operating.

Rehearse. Time should be made available for rehearsals for flame attack. Rehearsals should be conducted on ground similar to the terrain to be traversed and against a point resembling the objective. If the attack is to be made at night, rehearsals should be conducted at night.

DEFENSIVE FLAME USE

The use of flame weapons can be a major factor in the successful defense of any position. Flame weapons are particularly effective in disrupting the final stages of an enemy assault. The short range of flame weapons, however, restricts their employment and requires that they be carefully located to obtain the best advantage. The longer range of the rocket launcher increases that weapon's flexibility.

The following flame weapons/munitions can be used in the defense: M202A1 and FFEs. These weapons are integrated into defensive fire plans to supplement or reinforce other fires. Defensive flame fire plans may employ flame weapons uniformly within unit areas, massed at likely avenues of approach against anticipated massed enemy assaults, or may deploy them in reserve blocking positions ready for use in the counterattack. Particular attention is given to the resupply or replacement of empty flame weapons to ensure sustained support for the defense.

Flame weapons are most effective when integrated into the plan for fire support and the obstacle plan. They are used to supplement or reinforce other defensive fires or to defend a small sector not covered by other weapons.

The basic considerations of defense apply to the use of flame:

Proper use of terrain. Flame teams are located on key terrain on the perimeter of the platoon defense areas. FFEs may be emplaced in the gaps between platoons, in approaches to the position, or on key terrain forward of the battle position that the defending force does not plan to hold, and in blocking positions in depth.

Defense in depth. FFEs are placed in likely areas of penetration. The use of these expedients is coordinated with counterattacking forces.

Mutual support. FFEs should be integrated into final protective fires and should be emplaced to provide mutually supporting area coverage. A technique is to use FFEs to fill gaps between indirect fire targets and force or canalize enemy troops into final protective fires.

All-round defense. FFEs may be positioned to protect the flanks and rear of the position.

The fire plan. FFEs can be used to supplement the long-range and close defensive fires of mortars and artillery. However, coordination is required to prevent duplication of effort and destruction of the FFEs by friendly fires. FFEs can also be used in internal defense

operations to counter ambush, clear underbrush, illuminate defensive areas, serve as warning devices, and inflict casualties on the attacking troops.

Reinforcement of obstacles. Natural and artificial obstacles can be reinforced or extended by flame weapons. For example, flame fuel floats and burns on water and can be used on shallow streams to prevent assaulting foot troops from crossing. FFEs can be used as floating flame devices. FFEs must be used carefully to avoid damaging mines or destroying camouflage.

Antitank measures. Armored vehicles can often move safely through flame fuel burning on the ground if the area is traversed quickly and the flames are not high enough to be sucked in through vents. However, flame fired directly on a tank can neutralize it by obscuring the driver's vision, seeping inside through vents, or setting the tank afire. The minimum effect is profound fear and decreased efficiency of the tank crew. FFEs may be located on probable tank approaches.

Brush and forest fires. Flame weapons must be used carefully to avoid starting brush and forest fires that may hinder the defense. When it is desirable to start fires deliberately, consider the following factors:

- Probable effect on enemy operations.
- Danger to friendly troops and installations.
- Effect on friendly observations.
- Effect on future friendly operations.
- Effect on environment.
- Effect on noncombatants.

CHAPTER 3

Flame Fuels

The three types of flame fuels are unthickened, thickened, and triethylaluminum (TEA). Unthickened fuel is a thin, pourable, highly flammable liquid composed of gasoline and oil. Thickened fuel is a thick, jellylike substance ranging in consistency from a pourable liquid to a rubbery, very thick gel. TEA is a thickened pyrophoric substance similar to white phosphorus. It burns spontaneously at temperatures of 1,400 to 2,200 degrees Fahrenheit when exposed to air.

Use unthickened fuel in situations where range is not an important factor or when fuel is needed on short notice. Unthickened fuel has advantages: you can prepare it quickly and it is readily available; however, it has a short range of about 20 meters and is quickly consumed. Another disadvantage is that unthickened fuel offers little penetration of fortifications or fighting positions. It does not rebound effectively from surfaces.

Thickened fuel requires equipment, time, and personnel for mixing, aging, and transferring. Unless you store it in airtight steel containers, thickened fuel has an uncertain period of stability. However, thickened fuel burns longer than unthickened fuel and clings to a target. It splashes across surfaces and, therefore, is effective when employed during military operations on urbanized terrain (MOUT). Since you will use thickened fuel more extensively than unthickened fuel in flame field expedients, this chapter will primarily address thickened fuel.

Both thickened and unthickened fuels are used to kill, dislodge, and demoralize personnel, to neutralize fortifications, and to destroy flammable material. Burning unthickened/thickened fuel is very effective against personnel caught in the open.

THICKENED FLAME FUELS

Thickened fuel consists of a thickener and gasoline. The Army uses two different thickeners, M4 and M1.

M4 thickener is a fine white powder that is a by-product of petroleum processing. Even though M4 thickener is hydroscopic (absorbs water from the air), you may reseal a partially used container and store it for one day. M4 thickener comes in 2.5-pound cans or 100-pound drums.

M1 thickener is a coarse, light tan, granular material that is extremely hydroscopic. The presence of moisture in it decreases its ability to form a stable flame fuel. You should discard a partially used container of M1 thickener.

Thickened Fuel

Flame field expedients use number 3 flame fuel. The consistency of the fuel is based on a factor of 3 in determining the amount of thickener to add to a specific amount of gasoline. When mixing a batch of flame fuel, use the applicable equation for either M4 or M1 thickener.

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Thickened Flame Fuels

Storage

For M4 thickener, the equation is gallons of gasoline x fuel number = ounces of thickener required. For example, to mix 50 gallons of thickened flame fuel, calculate the amount of thickener needed as follows: 50 (gallons) x 3 (flame fuel) = 150 ounces of M4 thickener.

For M1 thickener, the equation is gallons of gasoline x fuel number x 2 = ounces of thickener required. For example, to mix 50 gallons of thickened flame fuel, calculate the amount of thickener needed as follows: 50 (gallons) x 3 (flame fuel) x 2 = 300 ounces of M1 thickener.

NOTE:

Although this publication addresses M1 thickener, it is not currently maintained in the active Army inventory. However, limited stocks exist in certain Reserve and National Guard units and some Allied armies.

Mixing Site

Mixing sites must be--

- Free of fire hazards.
- Located on firm, well-drained terrain.
- Convenient to supply delivery points for gasoline and thickener.
- Centrally located for fuel delivery to using units.
- Well-ventilated and outside of any enclosures such as buildings or tents.
- Posted with NO SMOKING WITHIN 50 FEET signs.

In addition, an appropriate (at least a 10-pound carbon dioxide) fire extinguisher should be at the site.

WARNING

Allow no smoking within 50 feet of gasoline or fuel. You must strictly enforce this rule. Post NO SMOKING signs in prominent places around an area where fuel is being mixed, handled, or stored. If NO SMOKING signs are not available, post guards.

Do not permit open flames, heated stoves, or other sources of heat that might cause ignition of gasoline fumes in the immediate vicinity of mixing and filling operations or where fuel is stored and handled.

Personnel

Use personnel experienced in mixing flame fuels. Thoroughly train inexperienced personnel before allowing them to mix flame fuel.

Containers

All containers used for mixing or storing flame fuels must be clean and ungalvanized. Zinc from a galvanized container will cause the fuel to break down.

Mixing

You can mix flame fuels either by hand or with an air source using the "bubbling" procedure.

Hand Mixing

Use hand mixing for small quantities of flame fuel. This method requires the following equipment:

- Clean, ungalvanized container or containers of gasoline.
- Bucket and funnel if transferring into smaller containers for use in flame expedient devices.
- One 10-pound carbon dioxide fire extinguisher.
- M4 thickener.
- Mixing paddle (wooden).

Use the following four steps for mixing by hand:

Step 1. Open container of gasoline.

Step 2. Open container of thickener and breakup lumps by hand. Add thickener to gasoline evenly over a 5 to 9 minute time span. Do not dump it into the fuel. Stir gasoline continuously while adding the thickener.

Step 3. Continue to stir mixture until fuel has the appearance of applesauce.

Step 4. Check fuel periodically during mixing to ensure that thickener has become evenly suspended within the gasoline. If the thickener begins to settle to the bottom, mix more slowly.

NOTE

At low temperatures (below 32°F for M4 thickener and 70°F for M1 thickener), longer mixing time is required with larger amounts of thickener. You may need as much as two hours for mixing in very cold conditions.

Mechanical Mixing

Mechanical mixing (also called "bubbling") uses mechanical equipment to prepare flame fuel. This equipment must be grounded before use to safeguard against static electricity. For details on grounding procedures, refer to technical manuals for the equipment to be used.

WARNING

Do not operate electrical apparatuses or other equipment likely to cause sparks within 25 feet of the mixing equipment.

The mechanical mixing method requires the following equipment:

- M4 compressor or vehicle with an air source.
- Two 25-foot air hoses.
- One 10-pound carbon dioxide fire extinguisher.
- Container or containers of gasoline.
- M4 thickener.

Use the following 11 steps for mechanical mixing:

Step 1. Position the M4 air compressor or vehicle with an air source 25 feet upwind from mixing area.

Step 2. Ground the M4 compressor and chock rear wheels of the vehicle.

Step 3. Connect both air hoses.

Step 4. Connect air hoses to the air source.

Step 5. Open the container of gasoline.

Step 6. Open the containers of thickener --*one at a time, as needed.* Breakup any lumps by hand.

Step 7. Start the M4 air compressor or vehicle. Turn on the air pressure to 4 to 5 psi.

Step 8. Insert the air hose into the container of gasoline until hose tip is at the bottom of the container.

Step 9. When the bubbling action begins, slowly pour the required amount of thickener into the gasoline container.

WARNING

Do not insert the air hose into gasoline container before activating the air supply; doing so will cause gasoline to enter the air hose and, on activation of the air supply, gasoline will splash out of the container. Wearing goggles will prevent splashing in eyes.

Step 10. Continue the bubbling process until fuel has the appearance of applesauce.

Step 11. Check the fuel periodically during mixing to ensure the thickener has become evenly suspended within the gasoline. If the thickener begins to settle to the bottom, mix more slowly.

Aging

Flame fuel allowed to age will have complete gelling of the gasoline and thickener. To age fuel, store it in sealed containers; leave a 5-percent void for expansion. You may use newly mixed fuel immediately after mixing, if necessary; however, aged fuel will bum more uniformly than newly mixed fuel.

Whenever possible, allow thickened flame fuel to age at the same temperature at which it was mixed. Fuel aged at extremely high or low temperatures has a tendency to break down after a short time.

At moderate temperatures, fuel prepared with M4 thickener requires 6 to 8 hours to age completely. Fuel prepared with Ml thickener requires 8 to 12 hours to age completely. The aging time increases as temperatures decrease.

Testing

Consistencies of thickened flame fuel may vary greatly even if mixed under identical conditions. This variation is due to different mixing techniques, slight differences in thickeners and gasoline from different manufacturers, the moisture content within the gasoline, and gasoline temperature.

Experienced personnel can estimate the characteristics of flame fuel by observing the fuel and handling it with a wooden mixing paddle. No definite rules exist for visual tests. Experience will help determine the characteristics of the gel to its probable flame

characteristics. In general, thickened fuels burn longer but have limited spread; thin fuels have greater spread but burn more quickly.

Fuel that is too thick will stand like gelatin. This is caused by too much thickener, too much stirring, or a gasoline temperature above 85 degrees F. Fuel that is too thin will flow like gasoline with a few lumps in it. This is caused by not enough thickener, too little stirring, or gasoline temperature below 32 degrees F. Once the fuel is fully mixed, you cannot change its consistency by adding fuel or thickener.

WARNING

Mix flame fuel only with a wooden paddle or stick. Do not put hands into the fuel to test consistency. Fuel on hands or clothing creates a fire hazard. Also, repeated skin exposure to gasoline may be harmful. Wooden paddles or other wooden items used to stir or test thickened flame fuels are potential fire hazards, Dispose of these as flammable waste or store them properly.

Water Detection

Moisture in either gasoline or thickener is very detrimental to the quality of the thickened flame fuel. Moisture will cause the fuel to break down rapidly.

You can easily detect water in gasoline by sampling the liquid at the bottom of the container. An alternate method is to stir the contents of the drum briskly, sample the gasoline (with a clear container) while it is still agitated, and let the sample settle. If water is present, it will be visible at the bottom of the clear container.

Water Removal

You may use any of several methods to remove water from gasoline before mixing thickened flame fuel. These methods include siphoning, decanting, and filtering.

WARNING

Containers of gasoline can be heavy and awkward to handle. You will need more than one individual to complete the water removal process, Gasoline can spill and cause a fire hazard or gasoline burns.

Siphoning

Tilt the drum containing-gasoline and let it stand in the tilt position for several minutes. Water in gasoline container will collect in the lowest portion and can be siphoned off.

Decanting

Let the gasoline container stand undisturbed for 10 to 15 minutes. Then very carefully pour the gasoline in one continuous motion, leaving any water that has settled to the bottom of the container.

Filtering

Filtering is a simple field expedient method for removing water from small amounts of gasoline. To filter, pour the gasoline through a shelter half spread loosely over a dry, open 55-gallon drum and bound securely to the drum (Figure 3-1). Gasoline will pass through the shelter half but water will not. You can filter fifty gallons of gasoline in 10 minutes at an average rate of 5 gallons per minute, which slows as the filtering continues.

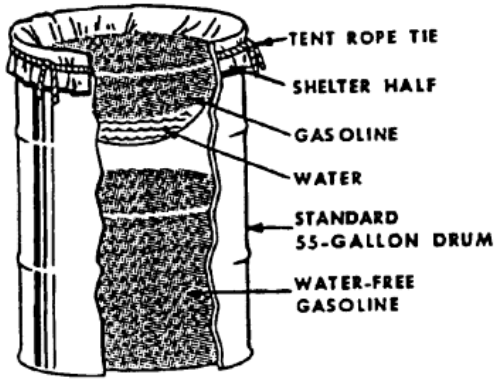


Figure 3-1. Example of a field expedient gasoline filter

Remove any water or silt remaining in the hollow of the shelter half before you filter more gasoline. Shelter halves used for this purpose are no longer serviceable; dispose of them after use.

Fuel Quality

Many factors interact when you mix thickened flame fuel. These factors are variable and may change the quality of the fuel.

Temperature

Gasoline temperature has a pronounced effect on the gelling of thickened flame fuel. For best results, gasoline temperature should be between 32 degrees F and 85 degrees F. At

gasoline temperatures below 32 degrees F (70 degrees F when M1 thickener is used), mixing time becomes prohibitive.

Thickener

The ratio of thickener and gasoline directly influences the properties of thickened flame fuel. A higher thickener content causes a greater consistency of the gel. Increasing the amount of thickener produces the following effects:

- Decreased mixing time.
- A more stable fuel in storage.
- Decreased amount of fuel burned in flight to a target.
- Increased burning time on target.

Improper Mixing

Strict adherence to the mixing procedures is required when you prepare flame fuel by hand. Insufficient stirring will cause unevenly suspended thickener in the gasoline. Two layers of fuel with different consistencies will result. Too much stirring may cause the applesauce-like gel to break down. This, in turn, will cause premature deterioration of aged fuel.

STORAGE

Gasoline is usually stored either in 5-gallon military gasoline cans or 55-gallon steel drums. Store thickeners as shipped.

Store flame fuel in clean, dry, ungalvanized containers. The most commonly used containers are 55-gallon drums of 14-gage or heavier steel with two bungs, but you may use 16- or 18-gage steel drums. Do not use drums more than five years old to store thickened flame fuel. Containers used to store thickened flame fuel must never be reused to store or handle automotive fuel. The residue of thickened fuel will lower the quality of the automotive fuel.

Locations

The storage location for thickened flame fuel or its ingredients should be as dry as possible and well camouflaged. Consider gasoline and thickened flame fuel as a field storage group and store them together, but never store them with any other field storage groups.

Procedures

You must take every precaution to ensure that water does not enter gasoline or thickened flame fuel containers during storage. Keep drums in storage tightly closed to prevent loss through evaporation and to prevent entry of moisture. To store, place drums of gasoline

and thickened flame fuel on their sides; when stored this way, water will not collect around the bungs and the rubber gaskets will remain soft.

Place containers of gasoline and thickened flame fuel on concrete blocks or skids. Inspect containers (cans or drums) weekly to ascertain that they are tightly closed and that no leakage has occurred.

Thickener alone is not flammable. However, it is classified as an ammunition item and must be stored in an ammunition supply point (ASP). Separate different lots of thickener in storage. Inspect stored containers periodically for corrosion.

Stability of Fuel in Storage

In general, the higher the consistency of thickened flame fuel the greater the storage stability. After it has been stored, you should check thickened flame fuel for deterioration before you use it. Deteriorated fuel will have large lumps of fuel surrounded by a watery fluid. Storage stability of thickened flame fuel is influenced by--

- Consistency.
- Quality of thickener.
- Quality of gasoline.
- Moisture content of gasoline and thickener.

CHAPTER 4

Exploding Flame Devices

Historically, exploding flame devices have been employed with great success in combat. In the Korean Conflict, the 8th Cavalry Regiment, 1st Cavalry Division, inflicted casualties on the Chinese Communists with strategically placed exploding flame devices. During combined operations in the Republic of Vietnam, the 10lst Airborne Division and the 2d Republic of Korea Marine Brigade made extensive use of FFEs to the south of Da Nang to clear vegetation and rid several areas of booby traps.

GENERAL INFORMATION

Exploding flame devices cause casualties by inflicting injuries from burning fuel and flying debris. These devices also have a great psychological effect that may deter or slow an enemy attack. All exploding flame devices consist of a container, incendiary fuel, and a firing system (burster and igniter) to scatter and ignite the fuel. The size of the area covered depends on the size of the container and the firing system used.

Components

Field expedient flame weapons generally consist of four basic components--a container, fuel, an igniter, and a burster. Appendix B contains detailed information on the proper use of demolition accessories.

Container

Anything that will hold the fuel, such as a standard issue military canteen or even a 55-gallon drum, can serve as a container.

Fuel

Fuel is a combustible liquid that produces an immediate fire, such as thickened or unthickened MOGAS.

Igniter

An igniter is an incendiary used to set the exploding fuel alight. M49 trip flares, incendiary grenades, M34 white phosphorus (WP) grenades (combat use only), or even small containers of raw gasoline may be used. An expedient method for employing raw gasoline as an igniter is to fill a used meals, ready-to-eat (MRE), bag with gasoline and

seal it with tape. This will produce enough immediate fire to ensure ignition of an FFE device.

Burster

A burster is an explosive charge that scatters the fuel. Examples of bursting charges include, but are not limited to, trinitrotoluene (TNT), composition C4, M4 field incendiary bursters, detonating cord, and M18A1 Claymore mines. See Appendix B for further information about demolition materials.

NOTE

Expedient battlefield illuminators do not detonate; there is no need for a burster when employing this type of FFE. Battlefield illuminators are discussed in Chapter 5.

CONTENTS

General Information

Electrically Initiated Devices

Bunker Bombs

Render Safe

Removal, dismantling, or otherwise rendering safe an exploding flame field expedient device that has been emplaced consists of removing the blasting cap, the igniter, and the FFE device.

WARNING

Only those personnel trained in safe handling of explosives and their components are authorized to perform render safe procedures.

Hasty Emplacement

For hasty or overnight defensive operations (in the absence of metal or plastic containers), dig holes in the ground and fill with premixed thickened fuel. Attach an exploding igniter (M34 WP grenade in combat only) to the device by detonating cord. Area coverage will vary, depending on size and shape of the hole, amount of thickened fuel, and the explosive charge used.

ELECTRICALLY INITIATED DEVICES

Controlled devices are fired using an electrical firing system. See Appendix A for details concerning the construction of electrical firing systems and proper testing procedures respectively.

5-Gallon Device

To construct the 5-gallon device (Figure 4-1), use these five-step procedures:

Step 1. Fill this device with thickened flame fuel. It can be rapidly emplaced either on the surface or in a V-trench.

Step 2. Prime (hasty whip) one M4 burster with 10 to 12 turns of detonating cord, leaving a 10-foot pigtail for a main line.

Step 3. Place the M4 burster inside the container.

Step 4. Attach two electric blasting caps (that have been tested) to a firing wire using a common series circuit.

Step 5. Attach both electric blasting caps to the main line by making a loop in the detonating cord and attaching the blasting caps to it. The device is ready to be fired.

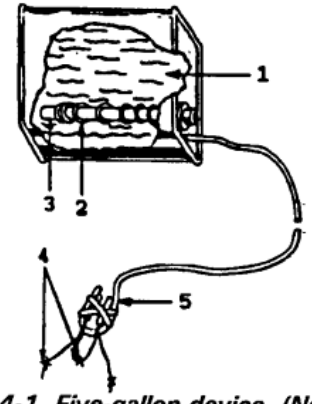


Figure 4-1. Five-gallon device. (Numbers correspond to steps in text.)

NOTE:

Non-electric blasting caps can also be used. See Appendix A for further information on the nonelectrical firing system.

Area coverage is approximately 20 to 30 meters in diameter. Use this small yet deadly device with anti-personnel mines to complement established mine fields. Although it is small, you may use this device against enemy targets such as wheeled vehicles, personnel in the open, and suspected enemy parachute drop zones.

Each 5-gallon flame device requires the following:

- 5-gallon container.
- Five gallons of gasoline.
- 25 feet of detonating cord.
- Two electric blasting caps.
- M4 field incendiary burster.
- 15 ounces of M4 thickening compound.

55-Gallon Device

The three devices described in the following paragraphs are basically defensive weapons designed for perimeter protection during static defense. You may employ these devices singly or in clusters for increased coverage. Additionally, you may emplace 55-gallon land mines (flame) in the center of road intersections to slow or stall the movement of an enemy convoy. Other uses for FFE include, but are not limited to, large-area coverage of suspected enemy aircraft landing zones for rotary wing aircraft and parachute drop zones.

Vertical Flame Mine with M4 Burster

Use the following nine steps to construct a vertical flame mine with M4 bursters (Figure 4-2):

Step 1. Fill device with thickened flame fuel and place in an upright position.

Step 2. Prime the drum with detonating cord (10 to 12 turns) around the base, leaving a 3-foot pigtail for attachment to the ring main.

Step 3. Prime two M4 bursters (three in combat) with 10 to 12 turns of detonating cord, leaving a 4-foot pigtail for attachment to the ring main.

Step 4. Place the M4 bursters inside the large bung of the drum.

Step 5. Place a ring main of detonating cord around the device, leaving 40 feet of detonating cord to be used as a main line.

Step 6. Attach both bursters and detonating cord around the base to the ring main by girth hitches with an extra turn.

Step 7. Place seven or eight sandbags on top of the drum to force the explosion down and outward in a 360-degree radius, keeping the entire detonation low to the ground.

Step 8. Attach two electrical blasting caps (that have been tested) to a firing wire, using a common series circuit.

Step 9. Attach both electric blasting caps to the main line by making a loop in the detonating cord and attaching the blasting caps to it. The device is ready to be fired.

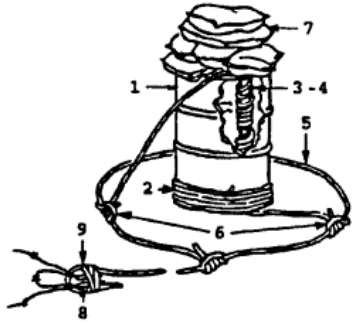


Figure 4-2. Example of a vertical flame mine with M4 bursters. (Numbers correspond to steps in text.)

Area coverage is approximately 80 to 100 meters in diameter. During combat, you will obtain maximum fragmentation by placing engineer screw pickets upright against the device. The pickets are then held in place by tightly wrapping barbed wire around the device.

Each 55-gallon flame land mine requires the following:

- 55-gallon container.
- Fifty gallons of gasoline.
- 100 feet of detonating cord.
- Two electric blasting caps.
- Two or three M4 field incendiary bursters.
- 150 ounces of M4 thickening compound.
- Seven or eight sandbags.

Vertical Flame Mine with Detonating Cord

To construct a vertical flame mine with detonating cord (Figure 4-3), follow the procedures described in steps 1 through 9.

Step 1. Fill device with thickened fuel and place in an upright position.

Step 2. Using a 6-foot length of detonating cord, tape one end over the spoon handle of an igniter (M49 trip flare or (in combat) M34 WP grenade).

Step 3. Prime the drum with detonating cord (seven to ten turns) around the base of the device leaving 40 feet to be used as a main line.

Step 4. Place a wooden stake near the device and attach igniter to it.

Step 5. Attach the igniter detonating cord to main line by use of a girth hitch with an extra turn.

Step 6. Place six or seven sandbags on top of the drum to force the explosion down and outward in all directions, keeping the entire detonation low to the ground.

Step 7. Remove the safety pin from igniter.

Step 8. Attach two electrical blasting caps (that have been tested) to a firing wire using a common series circuit.

Step 9. Attach both electric blasting caps to main line by making a loop in the detonating cord and attaching electric blasting caps to it. The device is ready to be fired.

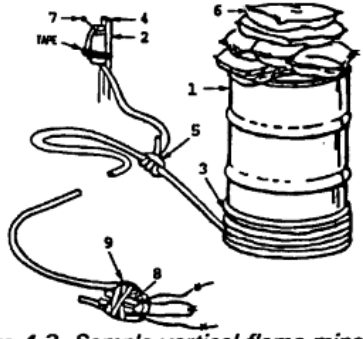


Figure 4-3. Sample vertical flame mine with detonating cord. (Numbers correspond to steps in text.)

Area coverage is approximately 50 to 80 meters in diameter. Each 55-gallon flame land mine requires the following:

- 55-gallon container.
- 50 gallons of gasoline.
- 200 feet of detonating cord.
- Two electric blasting caps.

- 150 ounces of M4 thickening compound.
- M49 trip flare or (in combat) M34 WP grenade.
- Six or seven sandbags.

Horizontal Flame Mine

To construct a horizontal flame mine (Figure 4-4), use the following procedures (11 steps):

Step 1. Fill the device with thickened flame fuel and place it on its side.

Step 2. Separately prime two 1.25-pound blocks of composition C4 or two l-pound blocks of TNT with seven to ten turns of detonating cord, leaving two 3-foot pigtails on each block of explosive for attachment to the ring main.

Step 3. Attach the blocks of explosives to each end of the drum. Two sandbags work well--one under and one against the device.

Step 4. Place a ring main around the device.

Step 5. Attach the pigtails from the blocks of explosives to the ring main by using girth hitches with an extra turn.

Step 6. Using a 6-foot length of detonating cord, tape one end over the spoon handle of an igniter (M49 trip flare or (in combat) M34 WP grenade.

Step 7. Place a wooden stake near the device and attach igniter to it.

Step 8. Attach the detonating cord from the igniter to the ring main by using a girth hitch with an extra turn.

Step 9. Remove the safety pin from the igniter.

Step 10. Attach two electrical blasting caps (that have been tested) to a firing wire using a common series circuit.

Step 11. Attach both electric blasting caps to the main line by making a loop in the detonating cord and attaching blasting caps to it. The device is ready to be fired.

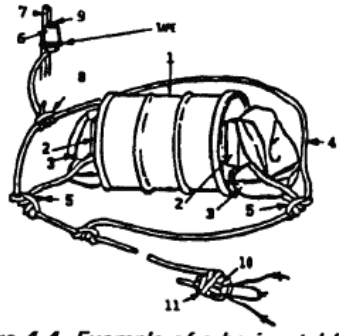


Figure 4-4. Example of a horizontal flame mine. (Numbers correspond to steps in text.)

Area coverage is approximately 80 to 100 meters laterally. Each horizontal 55-gallon flame land mine requires the following:

- 55-gallon container.
- 50 gallons of gasoline.
- 100 feet of detonating cord.
- Two electric blasting caps.
- 150 ounces of M4 thickening compound.
- M49 trip flare or (in combat) M34 WP grenade.
- Two 1.25-pound blocks of composition C4 or two 1-pound blocks of TNT.

Flame Fougasse Devices

The flame fougasse is a variation of an exploding FFE in which the flame is projected by explosive means over a preselected area. An excellent defensive weapon, the fougasse can also provide illumination as well as produce casualties. On Defensive Line Wyoming, during the Korean Conflict, elements of the 1st Cavalry Division emplaced 1,000 drums of FFEs in front of fighting positions. The drums were set in the ground at a 45-degree angle with the opening toward the enemy. Two examples of flame fougasses are the propellant charge container and the 55-gallon container.

Propellant Charge Container

To construct the propellant charge fougasse (Figure 4-5), use these procedures (20 steps):

Step 1. Using a metal cylinder or propellant charge container, knock a small hole into the bottom.

Step 2. Fabricate a pusher plate (wood or metal) the same size as inside diameter of the container.

Step 3. Thread the detonation cord through the small hole in the bottom of container.

Step 4. Prime (hasty whip) one block of composition C4 with seven to ten turns of detonating cord, leaving a 6-foot pigtail for attachment to the ring main.

Step 5. Put the explosive charge into a plastic bag. Make a small hole in the bag, thread detonating cord through the hole, and tape the bag shut.

Step 6. Place the charge inside the container pulling the pigtail from the propelling charge back through the hole in the bottom.

Step 7. Install the pusher plate on top of the explosive charge.

Step 8. Fill the container with thickened flame fuel. Place the lid on the container, but do not lock it in place.

Step 9. Dig a trench at an angle that will give maximum effect over the area selected for coverage (25 to 45 degrees).

Step 10. Carefully lower the device into the trench, making sure the bottom of the device is against the back of the trench and the detonating cord from the explosive charge is not pinched or crimped.

Step 11. Straighten the detonating cord pigtail from the explosive charge out behind the trench.

Step 12. Stack 20 to 30 sandbags on and around the device, ensuring that the detonating cord is not buried.

Step 13. Place a ring main of detonating cord around the device.

Step 14. Attach the pigtail from the explosive charge to the ring main using a girth hitch with an extra turn.

Step 15. Using a 6-foot length of detonating cord, tape one end over the spoon handle of the igniter (M49 trip flare or (in combat) M34 WP grenade).

Step 16. Place a wooden stake near the device. Attach the igniter to it.

Step 17. Attach the igniter detonating cord to the ring main using a girth hitch with an extra turn.

Step 18. Remove the safety pin from the igniter.

Step 19. Attach two electrical blasting caps (that have been tested) to a firing wire using a common series circuit.

Step 20. Attach both electric blasting caps to the main line by making a loop in the detonating cord and attaching blasting caps to it. The device is now ready to be fired.

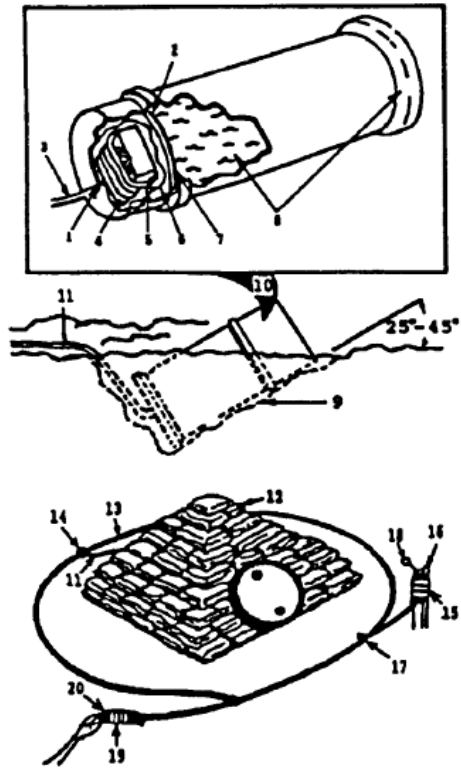


Figure 4-5. Example of a propellant charge fougasse. (Numbers correspond to steps in text.)

Area coverage is approximately 30 to 45 meters in diameter. Each propellant charge fougasse requires the following:

- metal cylinder or propellant charge container.
- Three gallons of gasoline.
- 100 feet of detonating cord.

- Two electric blasting caps.
- Nine ounces of M4 thickening compound.
- M49 trip flare or (in combat) M34 WP grenade.
- 1.25-pound block of composition C4.
- Twenty to thirty sandbags.

55-Gallon Container

To construct a flame fougasse using a 55-gallon container (Figure 4-6), follow these 17 steps:

Step 1. Prepare thickened flame fuel in a 55-gallon drum by mixing 150 ounces of M4 thickening compound to 50 gallons of gasoline while agitating it vigorously.

Step 2. Prime two blocks of TNT or composition C4 with seven to ten turns of detonating cord leaving 2 6-foot pigtails for attachment to the ring main.

Step 3. Dig a trench at an angle that will give maximum effect over the area selected for coverage (25 to 45 degrees).

Step 4. Dig a small depression in the back of the trench to place the explosive charge.

Step 5. Carefully place the explosive charge into the depression and straighten the detonating cord pigtail from the explosive charge up and out behind the trench.

Step 6. Carefully lower the device into the trench, making sure the bottom of the device is against the back of the trench and the detonating cord from the explosive charge is not pinched or crimped.

Step 7. Lift the device up. Place one sandbag under the front and hasty whip seven to ten turns of detonating cord around the top of the drum, leaving 2 4-foot pigtails.

Step 8. Remove sandbag and lower the device into place.

Step 9. Stack 100 to 120 sandbags on and around the device, ensuring that the detonating cord is not buried.

Step 10. Place a ring main of detonating cord around the device.

Step 11. Attach the pigtails to the explosive charge and the top of the drum ring main, using a girth hitch with an extra turn for each.

Step 12. Using a 6-foot length of detonating cord, tape one end over the spoon handle of the igniter (M49 trip flare or (in combat) M34 WP grenade).

Step 13. Place a wooden stake near the device. Attach the igniter to it.

Step 14. Attach the igniter detonating cord to the ring main using a girth hitch with an extra turn.

Step 15. Remove the safety pin from the igniter.

Step 16. Attach two electrical blasting caps (that have been tested) to a firing wire using a common series circuit.

Step 17. Attach both electric blasting caps to the ring main by making a loop in the detonating cord and attaching the blasting caps to it. The device is ready to be fired.

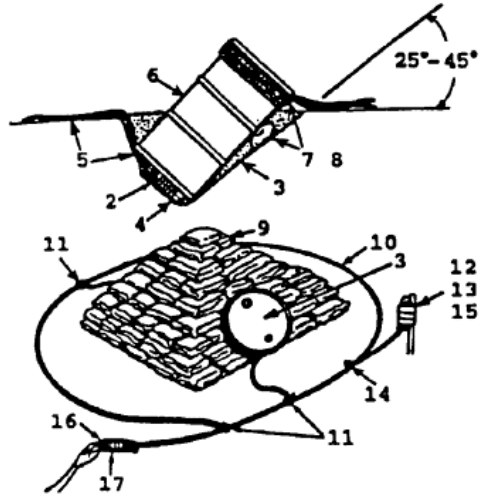


Figure 4-6. Fougasse made with a 55-gallon container. (Numbers correspond to steps in text.)

Area coverage is approximately 150 to 200 meters in front of the drum. Each 55-gallon flame fougasse device requires the following:

- 55-gallon drum.
- 50 gallons of gasoline.
- 100 feet of detonating cord.
- Two electric blasting caps.
- Two 1.25-pound blocks of composition C4 or two 1-pound blocks of TNT.
- 150 ounces of M4 thickening compound.
- M49 trip flare or (in combat) M34 WP grenade.
- 100 to 120 sandbags.

In combat situations, Claymore mine (M18A1) components can be used as the explosive charge at the drum bottom; it will detonate the expedient device and increase fragmentation effects. However, some method of ignition, such as an M49 trip flare or M34 WP grenade, is preferred.

Contact Devices

You may emplace all exploding flame devices for contact detonation as improvised flame mines. Since a lone soldier usually detonates a contact device, a 5-gallon oil can containing thickened fuel is sufficient. This weapon is most effective when positioned in open areas where obstructions will not decrease the fragmentation effect against personnel.

You will obtain the best results when you use the device in well-camouflaged positions approximately 2 meters (6 feet) above the ground in branches of trees, bushes, or hedges.

BUNKER BOMBS

Some forms of exploding flame devices lend themselves to a nonelectrical firing system rather than the electric method. One such device is the "bunker bomb." See Appendix A for further information on the nonelectrical firing system.

To construct the bunker bomb (Figure 4-7), follow these 7 steps:

Step 1. Fill the ammunition can three-fourths full with thickened flame fuel and secure the lid.

Step 2. Hasty whip the device with 15 turns of detonating cord around the center of the container, using 50 feet of detonating cord. Leave 2-foot pigtails for attaching the igniter and the nonelectrical blasting cap.

Step 3. Tape the igniter (M49 trip flare or (in combat) M34 WP grenade to the container handle.

Step 4. Place one detonating cord pigtail end over the igniter spoon handle. Tape it in place.

Step 5. Attach the M60 fuse igniter and the nonelectrical blasting cap to the M700 time fuse.

Step 6. Attach the nonelectrical firing system to the other pigtail by making a loop in the detonating cord and attaching the blasting cap to it.

Step 7. Remove the safety pin from the igniter (M49 trip flare or M34 WP grenade (in combat)). The device is ready to be fired.

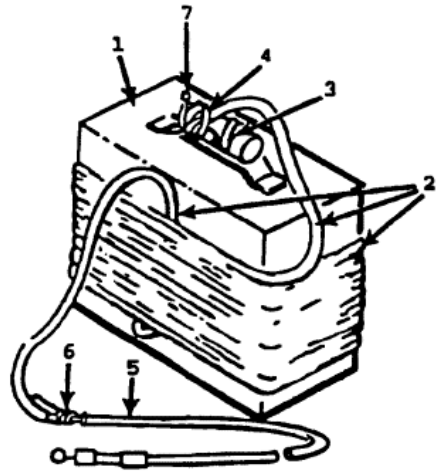


Figure 4-7. Example of a bunker bomb made from an ammunition can. (Numbers correspond to steps in text.)

WARNING

1. Carry the device only by the handle. Never use the igniter as a handle.

2. Remove the trip flare igniter safety pin only when it is time to use the device.

3. Use extreme caution when handling or carrying nonelectrical firing systems. Protect blasting caps from shock and extreme heat. Do not allow the time fuse to kink or become knotted. Doing so may disrupt the powder train and cause a misfire.

4. Prime detonating cord only when it is time to use the device.

5. Remove the time fuse igniter safety pin when it is time to use the device.

One ammunition can flame bunker bomb requires the following eight items:

- Small-arms ammunition container.
- Gallon of gasoline.
- Fifty feet of detonating cord.
- Nonelectric blasting cap.
- M60 fuse igniter.
- Seven and a half feet of M700 time fuse.

- Three ounces of M4 thickening compound.
- M49 trip flare or (in combat) M34 WP grenade.

Area coverage is approximately 5 to 10 meters in diameter. The bunker bomb is designed as a portable FFE device to be used during mobile defensive operations or raids into enemy rear areas during deep operations. This device is ideally suited for use in built-up areas during mobile operations in urban terrain.

CHAPTER 5

Flame Illuminators

The main purpose of flame illuminators is to provide extended burning time with maximum illumination, although they may also produce casualties. You may use flame illuminators for warning as well as illumination by contact detonation. This chapter discusses some improvised flame illumination devices used for limited battlefield illumination.

Flame illuminators vary and may be constructed of many differing components. FFE illuminators include 5- or 55-gallon flame illuminators, hasty flame illuminators, water illuminators, field expedient illuminators, Husch flares, and illuminated signal arrows.

5- OR 55-GALLON FLAME ILLUMINATORS

You can construct a flame illuminator (Figure 5-1) from a 5-gallon or a 55-gallon drum filled with thickened fuel, tightly sealed, and set into a hole with the top slightly below ground. Five turns of detonating cord are wound around the inside edge of the drum top and tightly tamped with mud. When detonated, the detonating cord cuts off the drum top and an M49 trip flare or M34 WP grenade (in combat only) placed on top of the drum, ignites the thickened fuel.

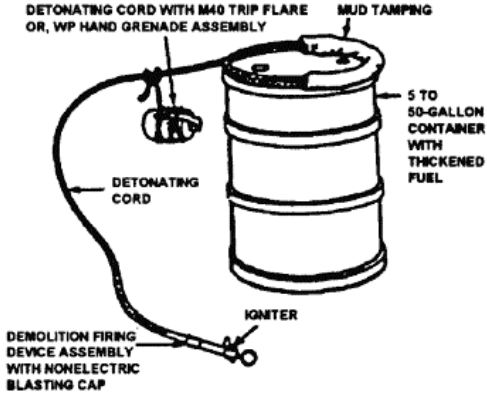

DETONATING CORD WITH M40 TRIP FLARE OR, WP HAND GRENADE ASSEMBLY
MUD TAMPING
5 TO 50-GALLON CONTAINER WITH THICKENED FUEL
DETONATING CORD
IGNITER
DEMOLITION FIRING DEVICE ASSEMBLY WITH NONELECTRIC BLASTING CAP

Figure 5-1. How to rig a 5- or 55-gallon flame illuminator.

The fuel will burn for several hours. However, you may control burning time somewhat by the size of container used, the thickness of the fuel mixture, and the addition of straw or dirt to the thickened fuel.

Each 55-gallon flame illuminator requires the following ammunition:

- 100 foot of detonating cord.
- Nonelectric blasting cap.
- Seven and a half feet of M700 time fuse.
- M60 fuse igniter.

- Electric blasting cap.
- 150 ounces M4 thickening compound.
- M49 trip flare.
- M34 WP grenade (in combat).

- 50 gallons of gasoline

CONTENTS

5- or 55-Gallon Flame Illuminator

Hasty Flame Illuminators

Water Illuminators

Field Expedient Illuminators

Husch Flares

Illuminated Signal Arrows

HASTY FLAME ILLUMINATORS

Construct hasty flame illuminators (fired within 24 hours after emplacement) by digging shallow holes or trenches in selected avenues of approach, filling with thickened fuel, and adding an igniter system. Can be ignited with electric blasting caps.

Ammunition requirements depend on the number of holes or trenches dug. Each device requires the following ammunition:

- Five feet of detonating cord.
- Nonelectric blasting cap.
- Seven and a half feet of M700 time fuse.
- M60 fuse igniter.
- Electric blasting cap.

- M49 trip flare.
- M34 WP grenade (in combat).
- Gasoline as required.

WATER ILLUMINATORS

Water illuminators are devices made by pouring gasoline, oil, or thickened fuel on the surface of calm water and igniting it. This hasty illuminator not only provides illumination but can be a formidable obstacle as well. Water illuminators should be used in combat only and not in training.

FIELD EXPEDIENT ILLUMINATORS

Use field expedient illuminators for defensive perimeters. Construct these devices using number 10 food cans, empty .50-caliber ammunition cans, or similar containers (Figure 5-2).

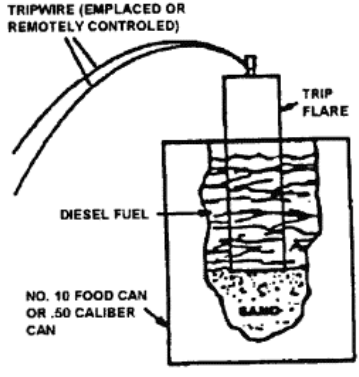


Figure 5-2. Sample field expedient illuminator.

Construct field expedient illuminators by filling the container halfway with sand, then filling the remaining with diesel fuel, and covering with paper. A trip flare is used to ignite the fuel. Each container should be strategically placed (with trip wires or wires for command-controlled detonation) at 50-meter intervals within the forward edge of a defensive perimeter.

On activation, these devices provide illumination for about 45 minutes.

HUSCH FLARES

The Husch flare (Figure 5-3) uses burning vapor of thickened flame fuel to provide battlefield illumination.

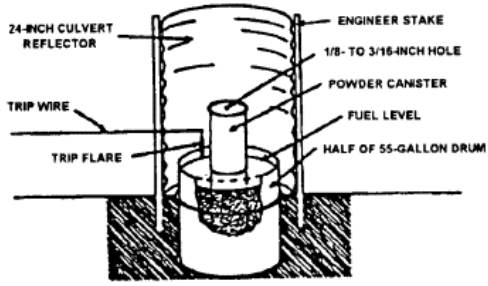


Figure 5-3. Cutaway, showing composition of a Husch flare.

Each Husch flare is constructed from a sealed metal container (powder canister) that is three-quarters full of thickened fuel and has a 1/8- to 3/16-inch hole in the top. Place the canister cap down in half of a 55-gallon drum that is three-quarters full of thickened fuel. A reflector assembly made from 24-inch culvert should extent about 24 inches above the top rim of the drum half. Husch flares can also be constructed with other similar components.

When you ignite the fuel in the drum half, heat from the burning fuel produces vapors within the canister. This vapor is expelled as a burning jet through the hole in the powder canister. Fuel in the drum half can be ignited with a trip flare.

The Husch flare, which is reusable, illuminates an area with a radius of about 50 meters for four to five hours. You can control burning time to some extent by the size of the container, the thickness of the fuel mixture, and the addition of straw or dirt.

ILLUMINATED SIGNAL ARROWS

An illuminated signal arrow (Figure 5-4) consists of a series of empty tin cans filled with an equal mixture of diesel fuel and JP4 (or equivalent) fuel. The number of cans on the stem of the arrow indicates the number of meters or increments to the enemy location (for example, each can may represent 100 meters).

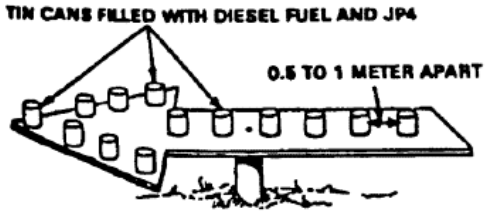


Figure 5-4. Example of an illuminated signal arrow.

When a unit is under attack, you must rapidly point the illuminated signal arrow in the direction of the attack and ignite the fuel in the cans. The arrow can be clearly seen by pilots of close air support aircraft. You may also use the signal arrow to mark landing zones and supply drop zones.

As the situation permits, you may arrange cans on an arrow-shaped board mounted on a spindle (Figure 5-4).

NOTE:
Distances per can should be stipulated in the unit SOP, SOI, or other guidance.

APPENDIX A

Demolition Skills for Constructing Flame Field Expedients

Demolition Skills
for Constructing
Flame Field Expedients This appendix provides the basic demolition skills required to construct flame field expedients. For further information on explosives and demolitions, See FM 5-250, *Explosives and Demolitions*, Jun 92.

DEMOLITION ACCESSORIES

Available demolition accessories include time blasting fuses, detonating cord, blasting caps, a cap crimper, a blasting cap test set, two blasting machines, a detonating cord clip, a weatherproof fuse lighter, a l-gallon mine, a field incendiary burster, thickening compound, and demolition materials. This appendix describes these items, their packaging, and any precautions.

M700 Time Blasting Fuse

A time blasting fuse sends a flame from a match or igniter to a nonelectric blasting cap or other explosive charge and provides a time delay. The delay allows soldiers to move to a safe distance before the explosion.

The M700 time fuse (Figure A-1) is a dark green cord, 0.2 inches in diameter, with a plastic cover. Depending on the time of manufacture, the cover may be smooth with single bands around the outside at l-foot or 18-inch intervals and double bands at 5-foot or 90-inch intervals. The bands provide easy measuring. The burning rate is approximately 40 seconds per foot.

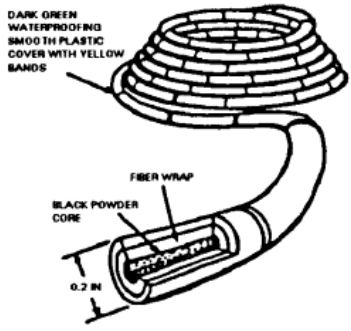


Figure A-1. Detail of M700 time fuse.

Time fuse M700 is packed in 50-foot coils, two coils per package, five packages per sealed container, and eight containers (4,000 feet) per wooden box.

CAUTION

You must always test the burning rate in the same manner as for a safety fuse. If burn rate is faster than 30 seconds per foot, do not use.

CONTENTS

Demolition Accessories

Misfires

Firing Systems

Testing Procedures

Priming Procedures

Detonating Cord

Detonating cord (Figure A-2) consists of a core of PETN or RDX in a textile tube coated with a thin layer of asphalt. Over this is an outer textile cover finished with a wax gum composition or plastic coating. Detonating cord transmits a detonating wave from one point to another at a rate of between 20,000 and 24,000 feet per second. Use it to prime and detonate other explosive charges. When you detonate its explosive core with a blasting cap or other explosive device, the detonation wave transmits to an unlimited number of explosive charges.

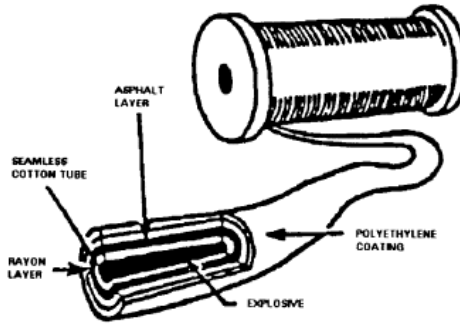


Figure A-2. Detail of detonating cord.

Detonating cord is packed in 1,000-foot spools, one spool per package, three packages (2,000 feet) per wooden box.

CAUTION

When using detonating cord to detonate underwater charges left in place several hours before firing, seal the ends with a waterproof sealing compound to keep out moisture. A 6-inch free end will also protect the remainder of the line from moisture for 24 hours. In priming, kinks or short bends that may sharply change the direction of detonation and thus cause misfires should be avoided.

Blasting Caps

Blasting caps are used for detonating high explosives. They are designed for insertion into cap wells and are also the detonating element in certain firing devices. Use the special military blasting caps to ensure positive detonation of the generally less-sensitive military explosives. Two types--electric (M6) and nonelectric (M7)--are used in military operations. Electric blasting caps are packed six per package (Figure A-3).

Figure A-3. Electric blasting cap.

M6 Electric Blasting Cap

Electric blasting caps have lead wires of various lengths for connection into a circuit. The most commonly used are 12 feet long. To prevent accidental firing, they have a short-circuiting shunt that you must remove before using the cap. If the cap is without a shunt, you may twist the bare ends of the lead wires together to provide the shunting action. The M6 special electric blasting cap (Figure A-4) is the standard issue electric blasting cap.

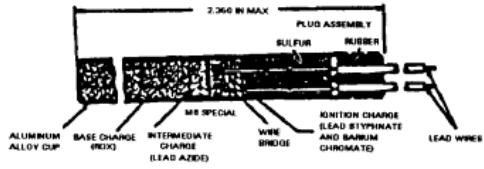


Figure A-4. Composition of M6 electric blasting cap.

CAUTION

Handle electric blasting caps with care. Blasting caps are extremely sensitive and may explode unless handled carefully. Like all blasting caps, electric blasting caps must not be tampered with and must be protected from shock, static electricity, and extreme heat.

M7 Nonelectric Blasting Cap

You may initiate nonelectric blasting caps by time blasting fuse, firing devices, and detonating cord. The M7 special blasting caps (Figure A-5) are flared at the open end to easily insert the time fuse. M7 caps are the standard issue nonelectric blasting caps.

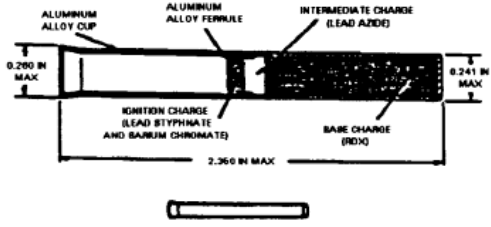


Figure A-5. Detail of M7 special nonelectric blasting cap (military).

CAUTION

Handle nonelectric caps with care. Blasting caps are extremely sensitive and may explode unless handled carefully. Do not tamper with caps and protect them from shock and extreme heat. Because they are difficult to waterproof, do not use these caps to prime charges placed underwater or in wet areas.

M2 Cap Crimper

The rear portion of each M2 cap crimper jaw (Figure A-6) is shaped and sharpened for cutting time fuses. Use the front portion of the jaw for crimping nonelectric blasting caps. A stop on the handle limits the closing of the jaws to prevent interference with the burning of the powder train in the fuse or detonation of the cord when crimping nonelectric blasting caps. One leg of the handle is pointed for use in punching cap wells in explosive materials for easy insertion of blasting caps.

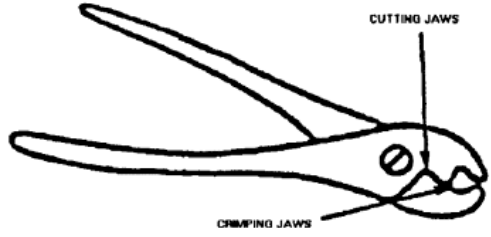


Figure A-6. M2 cap crimper.

Use the M2 cap crimpers to squeeze the shell of a nonelectric blasting cap around the time blasting fuse or detonating cord securely enough to keep it from being pulled off. The squeeze must not be enough to interfere with the burning of the powder train in the fuse or the detonation of the cord.

CAUTION

Because they are made of soft, nonsparking metal that will conduct electricity, do not use cap crimpers as pliers for any other purpose, as this damages the crimping surface.

M51 Blasting Cap Test Set

The M51 test set (Figure A-7) is a self-contained unit with a magneto-type impulse generator and two binding posts for attachment of firing leads. The test set is waterproof and may be used at temperatures as low as minus 40°F.

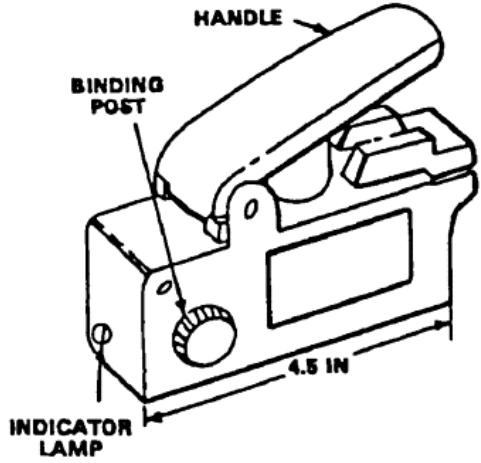


Figure A-7. M51 test set.

The test set was developed to replace the galvanometers for continuity testing of electrical firing circuits.

To ensure optimum useful life of the test set, keep it dry and handle it with care. Before using the set, ensure that it is in operating condition by following these three steps:

Step 1. Connect a piece of bare wire between the binding posts.

Step 2. Sharply depress handle while observing indicator lamp. If set is operative, lamp will flash.

Step 3. Remove wire and proceed to test firing circuit.

To perform continuity testing, connect the firing wires to the test set binding posts and depress the handle sharply. If there is a continuous, intact circuit, even one created by a short, the indicator lamp will flash.

M34 50-cap
Blasting Machine

The M34 blasting machine (Figure A-8) is a small DC electrical generator that produces adequate current (1.5 amperes) to initiate 50 electric blasting caps connected in series. It is 5 inches high and 2.5 inches wide.

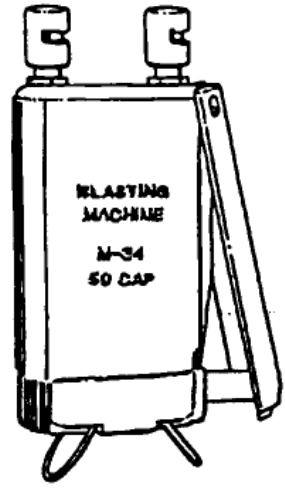


Figure A-8. M34 Blasting machine.

The M34 blasting machine is designed to detonate charges primed with electric blasting caps.

To ensure the machine works properly, perform steps 2 and 3 (*do not connect firing wires*). To detonate charges:

Step 1. Fasten the firing wires tightly to the terminals.

Step 2. Release the safety band from the handle bottom.

Step 3. Grasp the M34 blasting machine firmly with both hands and squeeze the handle vigorously several times until detonation occurs.

Detonating Cord Clip

The clip (Figure A-9) is a metal device that is approximately 2 inches long and 1 inch wide. It has a U-shaped bend at the top called a trough and a bend at the bottom called a tongue. The M1 detonating cord clip is used to hold strands of detonating cord either

parallel or at right angles to each other. You can make connections more quickly with these clips than with knots.

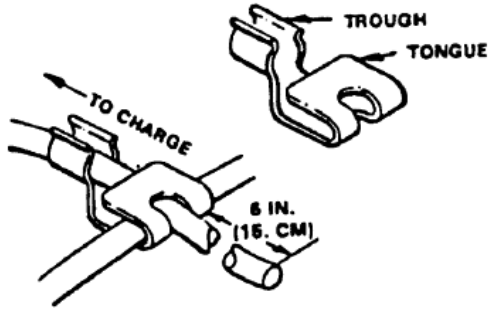


Figure A-9. M1 detonating cord clip used in branch-line connection.

Branch Lines

Connect branch lines by clipping the branch line with the U-shaped trough of the clip and the main line with the tongue of the clip.

Connecting Two Ends

Splice ends of detonating cord by overlapping them about 12 inches, using two clips, one at each end of the overlap, and bending the tongues of the clips firmly over both strands.

M60 Weatherproof Fuse Igniter

The M60 fuse igniter (Figure A-10) has a plastic body (barrel) 5 inches long with a safety pin attached through the barrel and the plunger. The plunger has a pull ring attached to it for easy use. The NSN is 1375-00-691-1671 and the DODAC is 1375-M766.

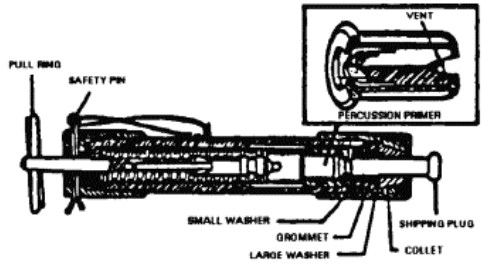


Figure A-10. M60 fuse igniter

The fuse igniter is designed to ignite time blasting fuses in any weather conditions and underwater if waterproofed. Operation is as follows:

Step 1. Unscrew fuse holder cap two or three turns but do not remove it. Press the shipping plug into the igniter to release the split collet, and rotate the plug as it is removed.

Step 2. Insert the free end of the time fuse in place of the plug until it rests against the primer.

Step 3. Tighten the cap sufficiently to hold the fuse in place, thus weatherproofing the joint.

Step 4. To fire, remove the safety pin, hold the barrel in one hand, and pull on the pull ring with the other, taking up the slack before making the final strong pull.

If there is a misfire, the M60 fuse igniter can be reset quickly without disassembly. Reset operation is as follows:

Step 1. Push the plunger all the way in and attempt to fire as before.

Step 2. If the M60 does not fire after three or four attempts to reset it, replace the igniter.

One-Gallon Mine

The 1-gallon mine (Figure A-11) is a rectangular 1-gallon can, 6 inches wide, 4 1/8 inches deep, and 10 9/16 inches high, fitted with a carrying handle and a threaded cap. Solder two short wires to the backside of the can for use when attaching a burster. You may fill one-gallon mine cans with thickened fuel to construct a flame mine field. The NSN is 1345-00-289-6938 and the DODAC is 1345-K260.

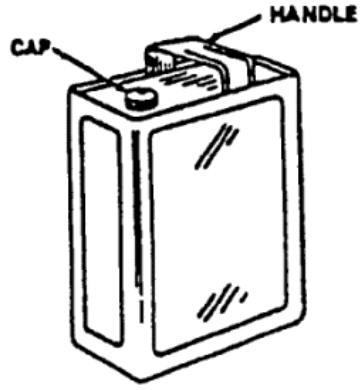


Figure A-11. One-gallon mine.

M4 Field
Incendiary Burster

The M4 field incendiary burster (Figure A-12) consists of a 12.25-inch by 1.25-inch burster tube assembly containing a plastic tube filled with tetryl pellets surrounded by a column of incendiary mix. It weighs 2.25 pounds. The burster tube has two bayonet-type fittings, a cap at one end, and a plug at the other. You may join two or more bursters together by removing the plug from one burster and the cap from another and coupling the open ends. A hole in the plug fitting accommodates the firing device, which may be a fuse, blasting cap, or detonating cord. A steel blasting cap adapter is furnished for each burster. The NSN is 1345-00-690-6909 and the DODAC is 1345-K010.

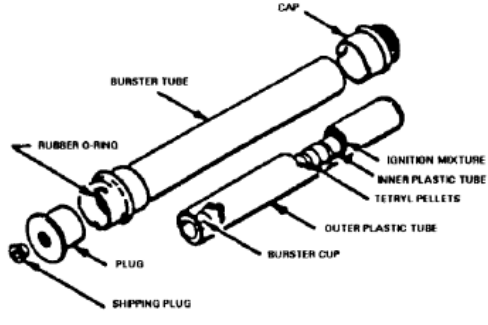


Figure A-12.
M4 field incendiary burster.

M4 field incendiary bursters are used primarily with field-improvised incendiary munitions filled with thickened fuel. The M4 bursts the fuel container, ignites the fuel, and scatters it over a large area. Each M4 burster has a bursting radius of 35 meters.

The M4 burster has a high-explosive filler. Handle it using the precautions given to high explosives.

WARNING

Handle with caution. The M4 burster has a high-explosive filler.

M4 Thickening Compound

M4 thickening compound is a fine, white powder. This dialuminum acid soap of isooctanic acid is a by-product of petroleum. It contains additives to prevent lumping. M4 thickening compound is used to convert liquid fuels to gels for use in flame field expedients. The NSN for the 2.5-pound can is 1365-00-926-4076, and the DODAC is 1365-K917. The NSN for the 25-pound pail is 1365-00-143-7139, and the DODAC is 1365-K920.

Demolition Materials

Units should plan in advance for the use of explosives and their components. (For training ammunition, base requisition procedures on unit and installation policies.) Two types of explosives used in the construction of flame field expedients are trinitrotoluene (TNT) and composition C4.

Trinitrotoluene

TNT is the most commonly used military explosive. It is employed as a bursting charge in constructing flame field expedients and as a standard explosive against which all other military high explosives are rated. TNT block demolition charges are issued in three sizes.

Uses. TNT block demolition charges are standard demolition charges and are used for all types of demolition work. The quarter-pound charge is used primarily for training purposes.

Advantages. TNT demolition charges (Figure A-13) have a high detonating velocity, are stable, and are relatively insensitive to shock or friction. TNT also has excellent water resistance and comes in convenient sizes, shapes, and packages.

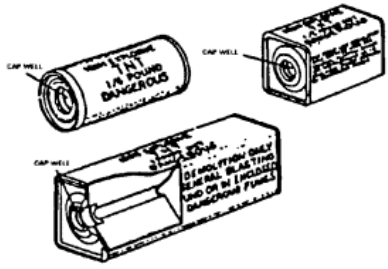


Figure A-13. Three sizes and shapes of TNT.

Limitations. Block demolition charges cannot be molded and are difficult to use on an irregularly shaped object. TNT is not recommended for use in closed spaces because the explosive gases are poisonous.

Composition C4

Composition C4 is a composite explosive containing 91 percent RDX and 9 percent nonexplosive plasticizers. Composition C4 replaced composition C3 as a demolition charge and may be used as a bursting charge. It is issued in two sizes: M112, 1.25 pounds, and M5A1, 2.5 pounds.

M112 Block Demolition Charge

The M112 (Figure A-14) block demolition charge consists of 1.25 pounds of composition C4 packed in a mylar film bag. On one surface there is pressure-sensitive adhesive tape protected by a peelable paper cover for quick emplacement. Composition C4 charges of old manufacturing dates are colored dull gray and are in a clear mylar bag. Charges of recent manufacture are white and packed in an olive drab mylar bag.

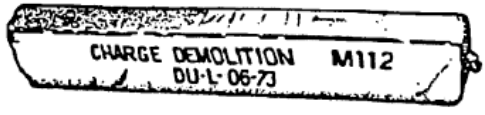


Figure A-14. M112 demolition block.

Uses. The M112 demolition block is used in all types of demolition work, primarily for cutting and breaching. Because of its moldability and high brisance (shattering effect), C4 is ideally suited for use as a bursting or propellent charge for exploding flame devices.

Advantages. M112 demolition block has an efficient shape and a handy size. It can be cut and molded for easy attachment to irregularly shaped objects. The color of the wrapper aids in camouflage.

Limitations. Its odd weight makes calculation of M112 charge weights difficult. Also, the adhesive tape will not adhere to wet or frozen surfaces. In addition, you should not use M112 in closed spaces because the explosion produces poisonous gases.

M5A1 Block Demolition Charge

The M5A1 consists of 2.5 pounds of C4 encased in a clear plastic container with a threaded cap well in each end. You can get bulk explosive by cutting open the plastic container.

Uses. Use the M5A1 in all types of demolition work, primarily for cutting and breaching. Because of its moldability and high brisance, C4 is ideally suited for cutting steel charges and for cutting irregularly shaped objects. C4 is insoluble in water and can be used for underwater demolitions.

Advantages. C4 is moldable from -20°F to +170°F. Because of its plasticity it can be cut and molded for easy attachment to irregularly shaped objects.

Limitations. The white color of C4 in demolition charge M5A1 is difficult to camouflage. Running water will erode C4 if it is not protected.

MISFIRES

Firing systems, whether electric or nonelectric, may occasionally fail to function properly. This creates a very hazardous situation. Handle misfires with extreme caution. You can reduce the possibility of a misfire by using combination dual-firing systems. To avoid misfires where charges are placed underground, use detonating cord to prime the explosive, keeping the blasting caps above ground.

Nonelectric Firing Systems

The most hazardous blasting operation is working on or near a misfire. If there is a misfire, delay investigation for at least 30 minutes after the expected time of detonation. This delay allows ample time for any explosion delayed because of a defective powder train in the fuse. Under certain combat conditions, however, immediate investigation may be necessary.

- Check all igniters and time fuses to determine if any did not burn.
- Check location of the blasting cap to determine if the primary was inadequate.

- For systems with detonating cord, locate the primed end of the detonating cord to determine if the blasting cap detonated but did not initiate the cord, or if the fault is in the initiating assembly.

WARNING

1. Only the individual who placed the charge should investigate and correct nonelectric misfires.

2. Anyone attempting to clear a nonelectric misfire must be trained in safe handling of explosives as well as the construction of nonelectric firing systems.

If the misfired charge is not tamped, lay a primed, l-pound charge beside it without moving or disturbing it, and again attempt to detonate the charge.

If the misfired charge has no more than a foot of tamping, try to explode it by detonating a new 2-pound charge placed on top. If this method is impractical, carefully remove the tamping using wooden or nonmetallic tools. Avoid accidentally digging into the charge. A constant check of the depth of the hole from ground level to the top of the charge will minimize the danger of striking the charge. When the charge has been uncovered to within 1 foot, insert and detonate a new 2-pound primer. Whenever possible, use detonating cord to prime underground charges and place the blasting cap above ground.

An alternate method of reaching a deep misfire is to dig a new hole within 1 foot of the charge and at the same depth. Place a 2-pound prime charge in the new hole to detonate the misfired charge. Use extreme care in digging the new hole to avoid striking the old misfired charge or placing the new charge too far away to induce detonation.

Electric
Firing Systems

To prevent misfires, one individual should be responsible for all electrical wiring of an FFE circuit. He or she should do all splicing to ensure--

- All blasting caps are included in the firing circuit.
- All connections between blasting cap wires, connecting wires, and firing wires are properly made. Short circuits are avoided.
- The number of blasting caps in any circuit does not exceed the rated capacity of the power source on hand.

Causes

Common causes of electric misfires include

- Blasting machine or power source inoperative or producing weak circuit output.
- Blasting machine or power source improperly operated.

- Defective and damaged connections causing a short circuit, a break in the circuit, or high resistance with resulting low current.
- Faulty blasting caps.
- Using blasting caps made by different manufactures on the same tiring circuit.
- Using more blasting caps than the power source permits.

Clearing

Because of the hazards from burning charges and delayed explosions, you must clear electric misfires with extreme caution. A burning charge may occur with the use of electric as well as nonelectric caps. Clear misfires of FFE charges primed with detonating cord and fired by electric blasting caps as follows:

Dual-Primed Charges

If the FFE charge is dual-primed electrically and below ground, wait 30 minutes before investigating; a burning charge may set off the second cap causing the main charge to detonate.

Single-Primed Charges

If the electric misfire is above ground and the FFE charge is not dual-primed, investigate immediately. If the system is below ground and not dual-primed, proceed as follows (12 steps):

Step 1. Check firing wire connections to the blasting machine or power source terminals to be sure contacts are good.

Step 2. Make two or three more attempts to fire the circuits.

Step 3. Attempt to fire again, using another blasting machine or source.

Step 4. Disconnect blasting machine firing wire. Before moving on to the FFE site, be sure you have shunted firing wires at the power source end of the circuit to avoid any possible static electric detonation.

Step 5. Check entire circuit, including the firing wire, for breaks and short circuits.

Step 6. If the fault is not above ground, very carefully remove the tamping material, if any, from around the FFE device, and avoid striking the electric blasting cap.

Step 7. Make no attempt to remove the primer or charge.

Step 8. If the malfunction is not located by removing the tamping material to within 1 foot of the charge, place a new electric primer and 2 pounds of explosive at this point.

Step 9. Disconnect blasting cap wires of the original primer from the circuit, and shunt the cap lead wires.

Step 10. Connect wires of the new primer in their place.

Step 11. Replace tamping material.

Step 12. Initiate detonation. Detonation of the new primer will fire the original charge.

Detonating Cord

Nonelectric or electric blasting caps attached to detonating cord may fail to function.

Nonelectric Blasting Cap

If a nonelectric blasting cap attached to detonating cord fails to function, follow these three steps:

Step 1. Delay investigation at least 30 minutes.

Step 2. Cut the detonating cord main line between the blasting cap and the charge.

Step 3. Fasten a new blasting cap with time fuse on the detonating cord.

Electric Blasting Cap

If an exposed electric blasting cap fastened to detonating cord fails to fire, follow these four steps:

Step 1. Disconnect the blasting machine immediately and investigate.

Step 2. Test the blasting circuit for any break or short circuit.

Step 3. Shunt the firing wire leads before leaving firing position to correct the problem.

Step 4. If necessary, replace the original blasting cap.

Failure of Branch Line

If the detonating cord main line detonates but a branch line fails, fasten a new blasting cap to the branch line; and fire separately.

Failure of Charge to Explode

If the charge is above ground and the detonating cord leading to the charge detonates but the charge fails to explode, follow these 5 steps:

Step 1. Delay investigation until certain the charge is not burning.

Step 2. If the charge is in the ground, wait 30 minutes.

Step 3. If the charge is intact, insert a new primer.

Step 4. If the charge is scattered by the detonation of the original detonating cord, re-assemble as much of the original charge as possible, place a new charge if necessary, and reprime.

Step 5. Make every attempt possible to recover all explosives scattered by misfire, particularly those used in training exercises.

Premature Detonation

Induced currents, lightning, or electric power lines may cause premature detonation.

Induced Current

The premature detonation of electric blasting caps by induced current from radio frequency (RF) signals is possible. Table A-1 shows the minimum safe distances in respect to transmitter power and indicates the distances beyond which it is safe to conduct electrical blasting, even under the most adverse conditions. This table applies to operating radio, radar, and television transmitting equipment.

Table A-1. Minimum safe distances.

Average or Peak Transmitter Power Watts	Minimum Distance to Transmitted (meters)
0–30	30
30–50	50
50–100	110
100–250	160
250–500	230
500–1,000	305
1,000–3,000	480
3,000–5,000	610
5,000–20,000	915

Mobile transmitters and portable transmitters are prohibited within 50 meters of any electric blasting caps or electrical firing system. If blasting distances are less than those shown in the table, the only safe procedure is to use a nonelectric system that cannot be prematurely detonated by RF currents.

Lightning

Lightning is a hazard to both electric and nonelectric blasting charges. A strike or a near miss is almost certain to initiate either type of system. Lightning strikes, even at remote locations, may cause extremely high local earth currents and shock waves that might initiate electric firing circuits. The effects of remote lightning strikes are multiplied by proximity to conducting elements, such as those found in buildings, fences, railroads, bridges, streams, and underground cables or conduit. The only safe procedure is to suspend all blasting activities during impending electrical storms.

WARNING

If you must transport electric blasting caps near operating transmitters or in vehicles (including helicopters) in which a transmitter is operated, then you must place the caps in a metal can with a snug depth of one-half inch. DO not remove the caps from the container near an operating transmitter unless the hazard has been evaluated and estimated to be acceptable.

Electric Power Lines

Do not conduct electric firing within 155 meters of energized power transmission lines. When it is necessary to conduct blasting operations at distances closer than 155 meters to electric power lines, use nonelectric firing systems or have the power lies shut off (see AR 385-63).

FIRING SYSTEMS

There are two types of firing systems: electric and nonelectric. Under normal conditions, construct FFE weapons using a dual-priming system.

Dual priming consists of two complete systems independent of each other and each capable of firing the same charge. It can be two electric systems, two nonelectric systems, or an electric and a nonelectric system. Dual priming increases the probability of a successful firing. Under emergency conditions or when equipment constraints make dual priming impossible, you may use single priming.

An electric dual-priming firing system consists of two independent electric circuits each with an electric blasting cap connected to a charge. The firing of either circuit will detonate all charges. Separate the firing wires for the two circuits to prevent the system from being cut by a single bullet or shell fragment. Place firing points at separate locations.

A nonelectric dual-priming firing system consists of two independent nonelectric systems for tiring a single charge or set of charges. If you are firing two or more charges simultaneously, lay out two detonating cord ring mains, and tie a branch line from each charge into each ring main.

A combination dual-priming firing system consists of an electric and nonelectric tiring system. Prime each charge both electrically and nonelectrically. Both electric and nonelectric systems are entirely independent of each other.

Electric Firing Systems

Electric firing systems detonate an explosive charge with an electric blasting cap. The basic priming materials consist of an electric blasting cap and a detonating cord.

Electric firing system basic assembly instructions include the following five steps:

Step 1. Prepare and place all explosive charges.

Step 2. Lay out firing wire from the charges to a predetermined firing position.

Step 3. Test firing wire as described in this appendix under "Testing Procedure."

Step 4. Test blasting caps that are to be used as described in FM 5-250.

Step 5. After blasting caps have been tested, twist the free ends of the cap lead wires together or shunt them with the short-circuit shunt provided to prevent an electric charge from building up in the cap lead wires.

Use the common series method to connect two or more charges fired electrically by a single blasting machine. Prepare a common series circuit by connecting one blasting cap lead wire from the first cap to one lead wire from the second cap and so on until only two end wires are free; then connect the free ends of the cap lead wires to the ends of the firing wire.

Nonelectric
Firing Systems

Nonelectric systems prime an explosive charge for detonation with a nonelectric blasting cap. The basic priming materials consist of --

- Nonelectric blasting cap and a time blasting fuse.
- M60 time blasting fuse igniter.
- Detonating cord (if more than one charge is to be detonated simultaneously).

To assemble the nonelectric firing system, follow these 10 basic assembly steps:

Step 1. Cut and discard a 6-inch length from the blasting fuse to prevent a misfire caused by the exposed powder absorbing moisture from the air.

Step 2. Cut off 3 feet of time blasting fuse to check the burning rate.

- *With* an M60 fuse igniter, attach the fuse to the igniter. Fire the M60 igniter and time the burning rate. Then compute the burning rate per foot by dividing the time in seconds by the length in feet.
- *Without* an M60 fuse igniter, split the end of the fuse, insert a match head into the split, light the match with another match, and note the time it takes the fuse to burn. Then compute the burning rate per foot by dividing the time in seconds by the length in feet.

Step 3. Cut the time blasting fuse long enough to permit the person detonating the charge to reach a safe distance by walking at a normal pace before the explosion. Make this cut squarely across the time fuse.

Step 4. Take a blasting cap from the cap box, and inspect it by looking into the open end. If foreign matter or dirt is present, hold the cap with the open end down and shake it gently or bump one hand against the other.

Step 5. Hold the time blasting fuse vertically with the square-cut end up and slip the blasting cap gently down over it so the flash charge in the cap is in contact with the end of the time fuse. It may misfire if not in contact. Never force the time fuse into the

blasting cap by twisting or any other method. If the end is flattened or is too large to enter the blasting cap freely, roll it between the thumb and finger until the size is reduced to permit free entry.

Step 6. After seating the blasting cap, grasp the time blasting fuse between the thumb and third finger of the left hand and extend the forefinger over the end of the cap to hold it firmly against the end of the time fuse. Keep a slight pressure on the closed end of the cap with the forefinger.

Step 7. Slide the second finger down the outer edge of the blasting cap to guide the crimpers and thus ensure accrate crimping even in darkness.

Step 8. Crimp the blasting cap at a point 1/8 to 1/4 inch from the open end (Figure A-15). Point the cap out and away from the body during crimping.

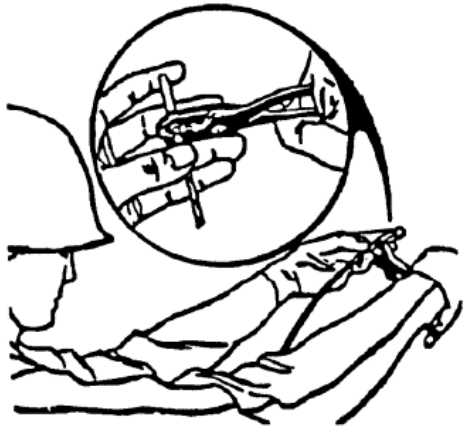


Figure A-15. Example of proper way to crimp a blasting cap.

WARNING

A crimp too near the explosive in the blasting cap may cause detonation

Step 9. Pass end of the time blasting fuse through the priming adapter. Then pull the cap into the cap well of the explosive, and screw the adapter into place. If no priming adapter is available, insert the blasting cap into the cap well and tie it in place with a string or fasten it with adhesive tape or other available material.

Step 10. Attach the M60 weatherproof fuse igniter as follows:

- Unscrew the fuse holder cap two or three turns but do not remove it. Press shipping plug into the igniter to release the split collet, and rotate the plug as it is removed.
- Insert free end of the time fuse in place of the plug until it rests against the primer.
- Tighten the cap sufficiently to hold the fuse in place and thus weatherproof the joint.

To fire the nonelectric system, remove the safety pin, hold barrel in one hand, and pull on the pull ring with the other, taking up the slack before making the final strong pull. If there is a misfire, the M60 can be reset quickly without disassembly by pushing the plunger all the way in and attempting to fire as before.

If a fuse igniter is not available, light the time blasting fuse with a match, using the following procedure: Split the fuse at the end, placing the head of an unlighted match in the powder train, and then light the inserted match head with a flaming match or by rubbing the abrasive on the match box against it (Figure A-16).

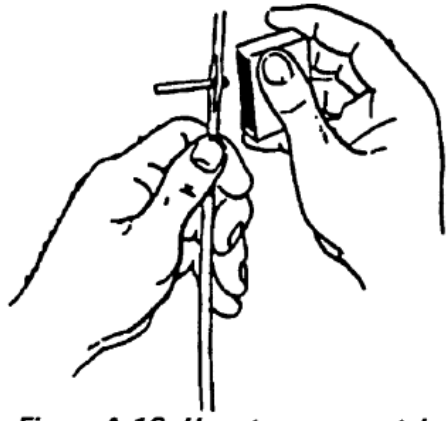


Figure A-16. How to use a match to light a time blasting fuse.

Detonating Cord Firing Systems

A detonating cord firing system is one of the most versatile and easily installed of all firing systems. It contains

- An electric system (an electric blasting cap, initiated by a blasting machine or other power source).

- A nonelectric system (a nonelectrical blasting cap initiated by a fuse igniter and a length of time blasting fuse). Use this method to initiate the detonating cord.
- Blasting caps, electric or nonelectric, attached to a point 6 inches from the free end of the detonating cord by numerous wraps of string, wire, cloth, or tape. The tip end of the cap must be in contact with the detonating cord.

Splices

Use a detonating cord clip or a square knot pulled tightly to splice the ends of detonating cord (Figure A-17). At least a 6-inch length must be left free at both sides of the knot. Then tape the free ends to prevent them from crossing over the detonating cord and thus cutting off the detonating wave at that point.

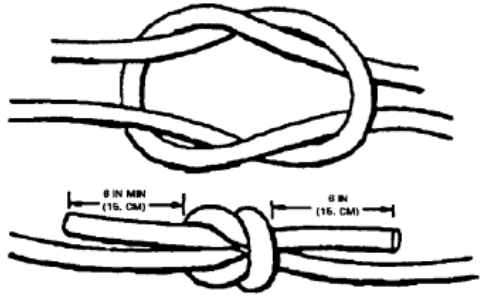


Figure A-17. Detonating cord splice using a square knot.

Fasten a branch line to a main line with a clip or a girth hitch with an extra turn (Figure A-18). The angle formed by the branch line must not be less than 90 degrees from the direction from which the blast is coming; at a smaller angle, the branch line may be blown off the main line without being detonated. At least 6 inches of the running end of the branch line is left free beyond the tie and taped down.

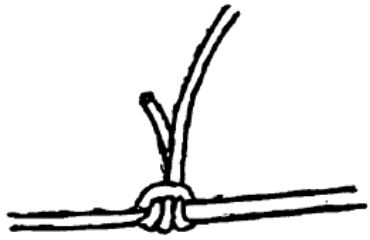


Figure A-18. Example of branch line connection, using a girth hitch with an extra

Ring Main

Make a ring main by bringing the main line back in a loop and attaching it to itself with a girth hitch with an extra turn (Figure A-19). This will detonate an unlimited number of charges.

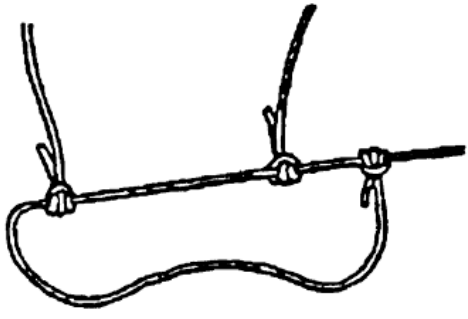


Figure A-19. Sample ring main with branch lines attached.

The ring main makes the detonation of all charges more likely because the detonating wave approaches the branch lines from both directions and the charges will detonate even if there is a break in the ring main. Make branch line connections perpendicular to the ring main. Avoid kinks in the lines, and curves and angles must not be sharp.

When making detonating cord branch line connections, avoid crossing lines. The cords may cut themselves and destroy the firing system.

TESTING PROCEDURES

Before priming an explosive charge electrically, carefully check all firing components. You must accomplish test procedures in the proper sequence. Otherwise, failure of the system or a premature detonation may occur.

Firing Wire

Use these procedures to test the firing wire of the M51 blasting cap test set and of the blasting galvanometers.

M51 Blasting Cap Test Set

Step 1. Check test set by connecting a piece of bare wire across the binding posts. The indicator lamp should flash when you squeeze the handle.

Step 2. Separate firing wire conductors at both ends and connect those at one end to the test set binding posts. Turn on the test set. Indicator lamp should not flash. If it flashes, the firing wire has a short circuit.

Step 3. Twist wires together at one end, connect those at the other end to the test set binding posts. Turn on the test set. Indicator lamp should flash. If it does not flash, the firing wire has a break.

Blasting Galvanometer

Step 1. Check galvanometers by holding a piece of metal across its terminals. If battery is good, the neddle will show a wide deflection of approximately 25 units (zero ohms).

Step 2. Separate firing conductors at both ends and touch those at one end to the galvanometers terminals. The needle should not move. If it moves, the firing wire has a short circuit.

Step 3. Twist the wires together at one end and touch those at the other end to the galvanometers terminals. This should cause a wide deflection of the needle-about 6.5 ohms or 23 to 24 units for a 500-foot length. No movement of the needle indicates a break, and slight movement indicates a point of high resistance that may be caused by a dirty wire, loose wire connection, or wires with several strands broken off at connections.

Electric
Blasting Cap

Use the following procedures to test the blasting cap of the M51 test set and of the blasting galvanometers.

M51 Blasting Cap Test Set

Step 1. Check the test set.

Step 2. Use the pointed handle of the M2 crimpers, make a hole in the ground deep enough to hold the entire blasting cap or have one sandbag handy.

Step 3. Remove electric cap from cardboard tube, wrap lead wires around fingers, and unwind lead wires from cardboard tube.

Step 4. Place the electric cap either in hole or under sandbag.

Step 5. Remove short circuit shunt from the lead wires of blasting cap.

Step 6. Attach one cap lead wire to one binding post and tie other lead wire to the other post. Squeeze test set handle. If the indicator lamp flashes, the blasting cap is satisfactory. If it does not flash, the cap is defective and you should not use it.

Step 7. Reshunt lead wires by twisting them together.

Step 8. Wrap lead wires loosely around cardboard tube and reinstall cap into tube. The blasting cap has now been tested and is ready for use.

Blasting Galvanometer

Step 1. Check the galvanometers for serviceability.

Step 2. Follow steps 2 through 5 described for the M51 test set.

Step 3. Touch one cap lead wire to one galvanometers post and the other lead wire to the other post. If the galvanometers needle deflects slightly less than it did when the instrument was tested, the blasting cap is satisfactory. If not, the cap is defective and you should not use it.

Step 4. Follow steps 7 and 8 described for the M51 test set.

Series Circuit

Follow these procedures to test series circuits of the M51 test set and the blasting galvanometers.

M51 Blasting Cap Test Set

Attach blasting caps lead wires to one binding post and tie other lead wire to the other post. Squeeze the test set handle. Indicator lamp should flash.

Blasting Galvanometer

Touch the free ends of blasting cap lead wires to one galvanometers post and the other lead wire to the other post. This should cause wide deflection in the galvanometers. If the galvanometers does not deflect widely, the circuit is defective.

Entire Circuit

Use the following procedure to test the entire circuit:

Step 1. Splice firing wires into a series circuit and move to firing position.

Step 2. When using the M51 blasting cap test set, connect the free ends of the firing wire to the binding posts. Squeeze the test set handle. Indicator lamp should flash. If the lamp does not flash, the circuit is defective.

Step 3. If the circuit is defective, shunt the wires. Then go down range and recheck the circuit. If you find a defective cap, replace it. Continue to test all caps and wires in the circuit. Then test the entire circuit again to make sure that you have found all defects before attempting to fire the charge. If you find a defective splice, resplice the wires using the Western Union pigtail method (Figure A-20).

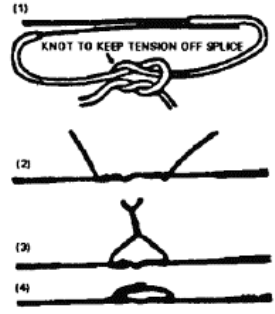


Figure A-20. Example of the Western Union pigtail method of splicing

Step 4. If you find a defective cap, replace it. Continue to test all caps and wires in the circuit. Then test the entire circuit again to make sure that you have located all breaks before attempting to fire the charge.

PRIMING PROCEDURES

You can accomplish the priming of high explosives through several approved techniques. The guidelines contained in this appendix explain and illustrate these procedures.

TNT
Demolition
Blocks

You can prime TNT demolition blocks either electrically, nonelectrically, or with detonating cord.

Electric Priming

As before, demolition blocks may or may not have threaded cap wells. If the blocks have threaded cap wells, use priming adapters if available. Proceed as follows:

Step 1. Untwist free ends of the lead wire and fasten them to the tiring wire.

Step 2. Pass the lead wires through the adapter slot and pull the cap into place in the adapter.

Step 3. Insert blasting cap into the explosive cap well and screw the adapter into place.

For demolition blocks without cap wells or priming adapters, complete the following procedures:

Step 1. If the block does not have a cap well, make one in the manner described for nonelectric firing.

Step 2. Untwist the free ends of the lead wire and fasten them to the firing wire.

Step 3. Insert the electric cap into the cap well and tie the lead wires around the block with two half hitches or a girth hitch with an extra turn. Allow some slack in the wires between the blasting cap and tie the wires to prevent any pull on the blasting cap.

Nonelectric Priming

Demolition blocks may or may not have threaded caps wells. Use priming adapters, if available, to secure the nonelectric blasting caps and the time blasting fuse to the demolition blocks with threaded caps wells.

If priming adapters are not available but blocks have threaded cap wells, prime them as follows (three steps):

Step 1. Wrap string or tape tightly around the block and tie it securely leaving about 6 inches loose on each end after making the tie.

Step 2. Insert the blasting cap with fuse attached into the cap well.

Step 3. Tie the loose string or tape around the fuse to prevent blasting cap from being separated from the block.

If demolition blocks do not have cap wells, follow this four-step procedure:

Step 1. With the pointed handle of the M2 crimpers, make a hole in the end of the block large enough to contain the blasting cap.

Step 2. Using string, wrap several turns around the explosive and tie any knot (or use tape). Position the tie so it will beat the top of the hole when the fused cap is inserted.

Step 3. Insert fused cap into the hole.

Step 4. Tie string (or use tape) around the time fuse at the top of the hole, with two half hitches.

Detonating Cord Priming

You may prime demolition blocks with detonating cord in several ways. The method that offers the greatest assurance of detonation is to affix a nonelectric blasting cap to the end of the detonating cord and place it in the demolition block similar to nonelectric priming methods. The system is then initiated by a nonelectric or electric assembly.

Common Method

To prime detonating cord with the common method, lay one end of a 4-foot length of detonating cord at an angle across the explosive. Give the running end three wraps around the block with the ends laying at an angle. On the fourth wrap, slip the running end under all wraps parallel to the other end and tighten it (Figure A-21). Initiate by an electric or nonelectric system.

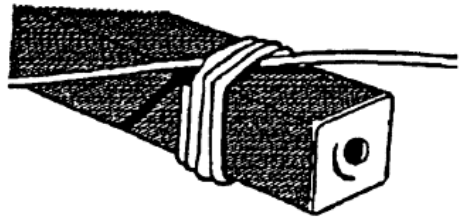


Figure A-21. Common method of detonating cord priming.

Alternate Method 1

To use the first alternate method, tie the detonating cord around the explosive block (on top of the booster if present) with a clove hitch with two extra turns. The cord must fit snugly against the block and the loops must be pushed close together (Figure A-22). Use an electric or nonelectric firing system taped into the loop made in the detonating cord to initiate the charge.

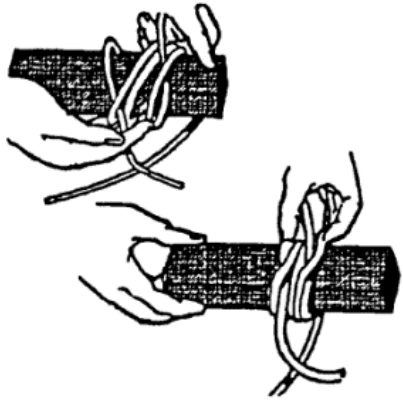


Figure A-22. Alternate method 1 of detonating cord priming.

Alternate Method 2 (Hasty Whip)

To use the hasty whip method, place a loop of detonating cord on the explosive with four wraps around the block and loop (Figure A-23). Pull the running end through the eye of the loop and tighten it. This method is also initiated by an electric or nonelectric system that is taped into a loop made in the detonating cord.

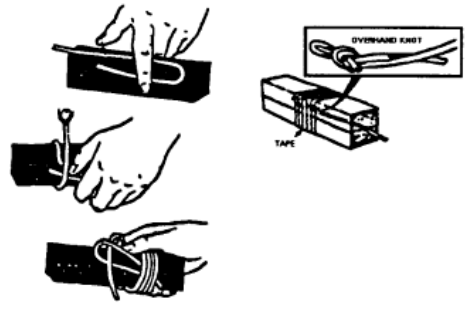


Figure A-23. Alternate Method 2 (hasty whip) of priming with detonating cord.

Composition C4
Demolition Blocks

You can prime composition C4 demolition blocks either electrically, nonelectrically, or with detonating cord.

Electric and Nonelectric Priming

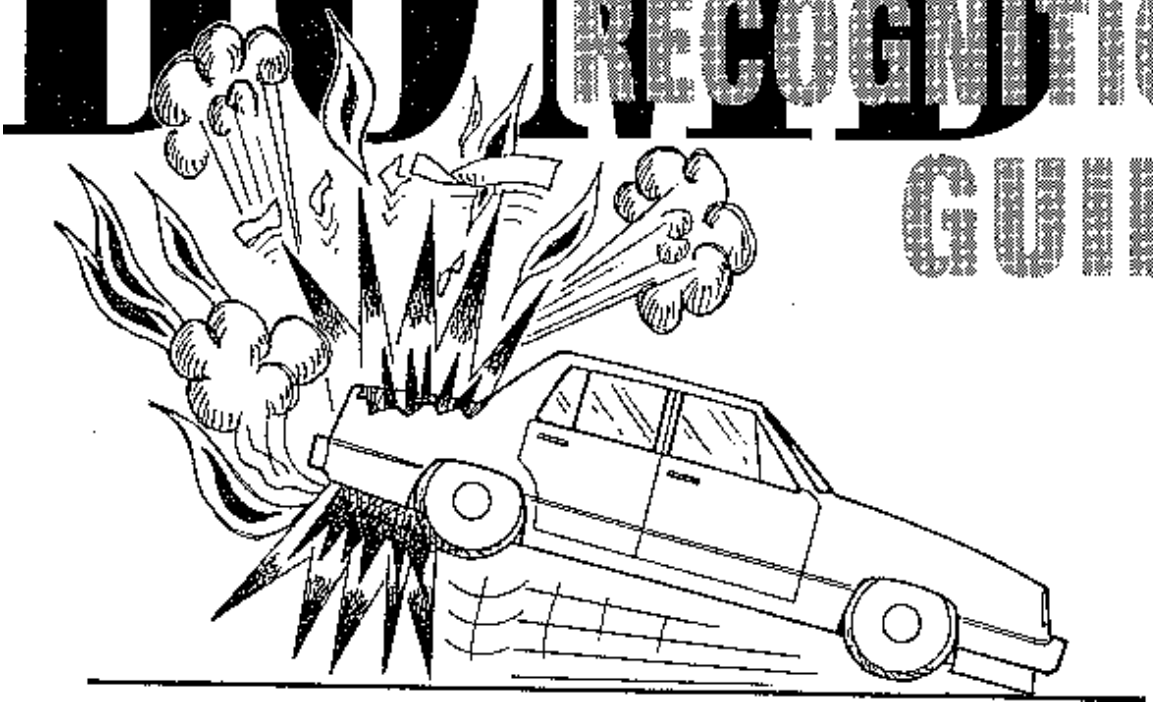
Whenever whole or portions of C4 blocks are used, prime similarly to demolition blocks without cap wells. You can cut C4 with a knife and then form it into almost any shape.

Detonating Cord Priming

To prime composition C4 explosive with detonating cord, form the knot. Insert the knot into the block of explosive. Ensure there is at least a half inch of explosive on all sides of the knot.

CAR BOMB RECOGNITION GUIDE

How They're Made, How to Detect Them



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* MANIFOLD FUSE IGNITION .
* F/X GAS0LINE MORTAR .
* FLARE IGNITION DEVICE .
* SHOTGUN SHELL DEVICE .
* RIFLE BULLET TIMED-DELAY DEVICE .
* MANHOLE DEVICE .
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* LIGHT-SENSITIVE TRUNK BOMB 3 .

Warning

This manual has been prepared for law enforcement officers, military officers, and counterterrorist specialists to assist in the recognition and identification of improvised explosive devices and booby traps emplaced in and around automobiles .
It is in no way intended to be a training manual for those with illegal intent, nor is it to be considered a substitute for professional, certified training in military and/or law enforcement explosive ordnance disposal (EOD) procedures .
Construction of improvised explosive or incendiary devices is highly illegal and extremely dangerous .The resulting end products are extremely unstable and unpredictable .Whenever dealing with explosives, special precautions must be followed in accordance with industry standards for experimentation and production.Failure to strictly follow such industry standards may result in harm to life and limb.
Therefore, the author, publisher, and distributors of this book disclaim any liability for any damages or injuries of any type that a reader or user of information contained within this book may cause or suffer from the use or misuse of said information .it is presented for academic study only .

Read This before You Go Any Further

This manual has been prepared for police bomb technicians and concerned citizens as a recognition manual only ! Because of the possibility that this book may fall into the hands of those with criminal intent, I make this stern warning
building a bomb is a major federal crime ! New antiterrorism laws have been enacted during the Bush and Clinton administrations specifically designed to deal with persons who build and deploy bombs .
If you are caught with a bomb or even just the components necessary to build a bomb, you will be treated like a hard-core terrorist and may very well spend the rest of your life in prison .
If that doesn’t deter you, then perhaps you should seriously consider the highly unstable and unpredictable nature of the devices illustrated in this book .in my opinion, anyone foolish enough to undertake the construction of a bomb deserves what he gets if it blows up in his face .

Introduction

In order to educate and enlighten peace officers as to the construction and deployment possibilities of car bombs, I have compiled the material in this book .It has been written for one purpose :

as an educational manual for those in the law enforcement community, especially police hazardous devices technicians (aka bomb technicians) .This book is not intended to educate criminals or provide them with the knowledge or inspiration to construct an actual explosive device .

Actually, there is nothing in this book that criminals don't already know .

In order for me to write this book objectively, I wrote it strictly from an "amoral" point of view, in much the same way as the nineteenth century German philosophers wrote their great works .I chose not to take the side of good or bad or right or wrong.Through this view, pure creativity can be unleashed .

This book resulted from my complete absorption with the late John Minnery's "Auto Suggestions" in Kill Without joy : The Complete How To Kill Book .If you have not read that book, you are really missing something .It is available from Paladin Press .it is my wish that this book take up where the ingenious Mr.Minnery's left off .

Car bombs have been with us since the gangland slayings of the 1930s, and their use is growing even today .Yet the technology has come a long way since the days of the gangsters planting six sticks of dynamite under the hood of the rival gang's car .An automobile has an electrical "nervous" system that can be tapped along many points .Only a basic knowledge of electronics is required to access it .

Also, every automobile contains a bomb built right into it : the gasoline tank .

The bomber only needs to do a bit of rewiring, drop the broken tail lamp, filament intact, into the gas tank, and, bingo, he has a bomb .When the victim turns on his lights, the filament flares up and ignites the gasoline vapors, which detonates the tank .

Terrorists have made things even more troublesome for the police bomb technician by not using any wiring in their bombs .

There is a glue that conducts electricity now on the market .The bomber need only affix the components to a board and run the glue to the components, thus creating the circuit .When the device is X-rayed, the bomb technician is unable to pick up the wiring layout .Many bomb techs don't even know this glue exists .

While we're on the subject of new terrorist tricks, here are a couple more that are of extreme importance to the police bomb technician .Booby-trapped blasting caps are the latest in the international terrorist's arsenal .Every bomb technician is advised to "attack the cap" when encountering a bomb .

Attacking the blasting cap means to cut the wire leads on the cap, thus rendering it inert .

Terrorists are now turning the tables on this technique by placing a hidden microswitch beneath or to the side of the blasting cap so that when the leads are cut and the cap is pulled out of the explosive device, the microswitch lever is released and the bomb explodes .

The microswitch is connected to a separate hidden circuit (e.g., in a hollowed-out stick of dynamite, beneath the device in a hollowed-out base, etc.) .

Another trick now favored by terrorists is the use of light-sensitive devices .The firing circuit incorporates a light-sensitive photocell .This closes the circuit when exposed to light .this type of bomb is commonly found in a briefcase, box, or automobile trunk .

Also of concern is the recent development of a product known as "X-Ray Enhancer Sheet" used by hospitals .When a sheet of this product is X- rayed, it glows .Thus when a bomber incorporates it in a light-sensitive bomb, the device cannot be X-rayed .If the police bomb technician X-rays the package to learn its contents, the enhancer sheet picks up the X-ray waves and the sheet glows .The light sensitive photocell receives the light, and the bomb explodes .

Beware of the above two products .They could drastically change the way bomb technicians disarm suspected explosive devices .

If you are a law enforcement officer, I hope you learn something new here .If you learn nothing else, just remember to keep your patrol car locked and your guard up on the home front .

Detecting and Responding to a car bomb .

The following procedures are recommended as a general outline that may be followed in the event of a suspected car bomb .Many techniques outlined here are of the author's own invention .Note that the author is not a certified bomb technician and that the information given hereafter could potentially cause harm or death to those using the information.

It is offered to certified police bomb technicians to provide possible new or improved options for dealing with car bombs .

"Prevention and awareness" is the best advice for those who think they could be the target of a car bomber .in this business, there is no such thing as being too paranoid .Simply becoming aware can have a profound effect and possibly even deter an assassin and save your life .

Always think from the criminal's point of view .if you were the bomber, how and when would you hook up the bomb ? Turn things over and over in your mind :

How would I do it ? Who are my enemies ? Where do I park my car ?

A bomb technician once told me, "Your worst enemy is almost always a friend" .And the people closest to you know your habits .

In the event a suspected car bomb is discovered, the hazardous devices technicians should be summoned at once.Normally, a uniformed officer arrives on the scene after the 911 call .He should not approach the targeted vehicle but should focus his efforts on evacuating the entire area .No one should be near doors or windows-if the device explodes, the shock wave could shatter glass for hundreds of yards, causing instant shrapnel .A rule of thumb is : if you can see anyone, he is too close .

The officer who arrives on the scene should close off the area in the safest possible manner, being careful not to get too elose to the suspected ear .He should summon additional manpower to close off all streets leading to the car .All police radio traffic must be done as far away as possible from the suspected ear, because electric blasting caps can be detonated by radio frequency alone (the leg wires act as antenna) .

Keep in mind that the bomber may be watching the entire procedure from a nearby vantage point such as a rooftop .He may be waiting for officers to get close to the car before detonating the bomb via remote eontrol .

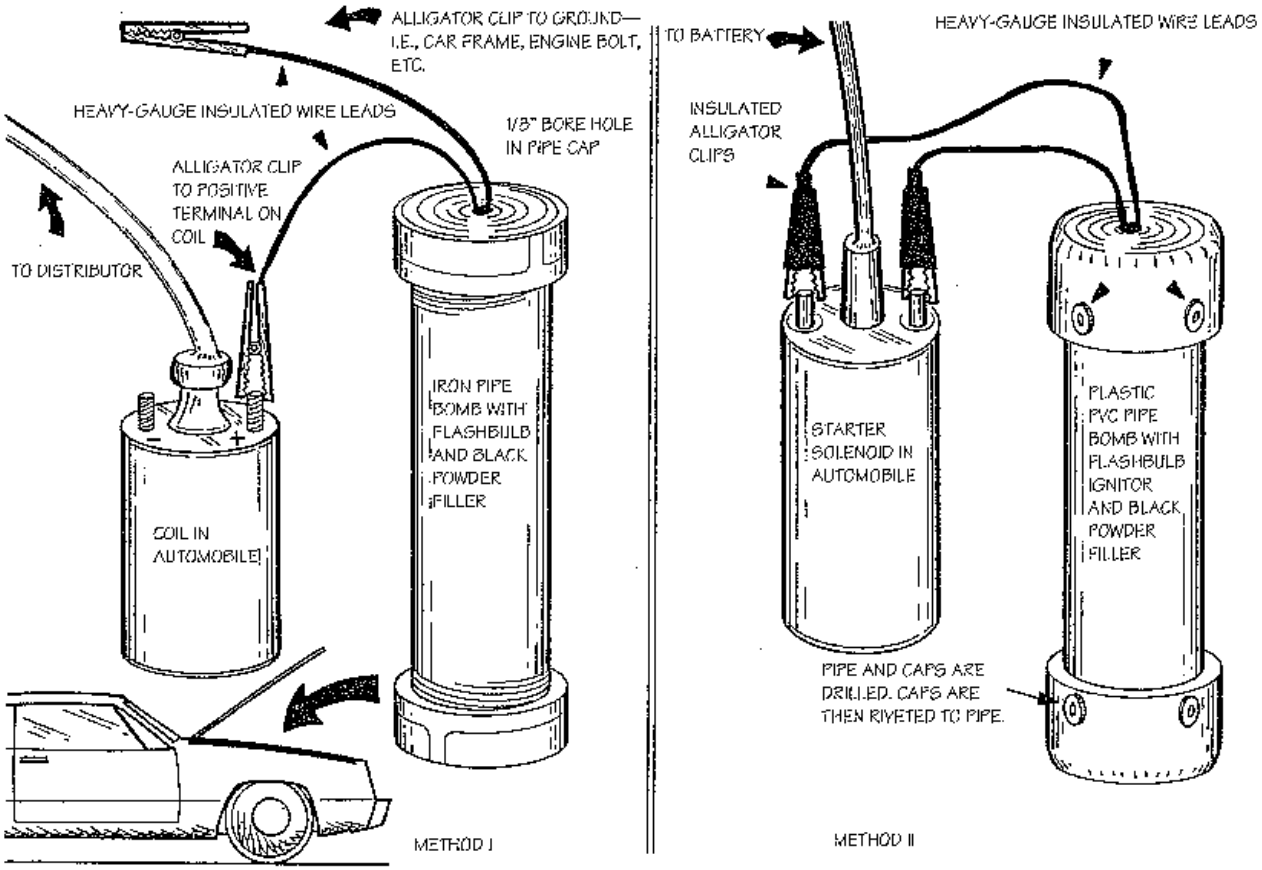
Any burglar or car alarm can be used to fire a bomb simply by substituting the horn or beeper for the electrie blasting cap or improvised detonator .This is why I advise you not to approach the vehicle, since such an action could fire the bomb .

Likewise, many devices could act as proximity sensors to fire a bomb .

A metal detector pointing away from the metal car could keep officers at bay .Even if the bomb technician approached it in nothing but his shorts, the metal detector could be made sensitive enough to pick up the metal fillings in his teeth .I know this sounds far-fetched, but anyone with a rudimentary knowledge of basic electronics could conceivably construct it ...and so much more .

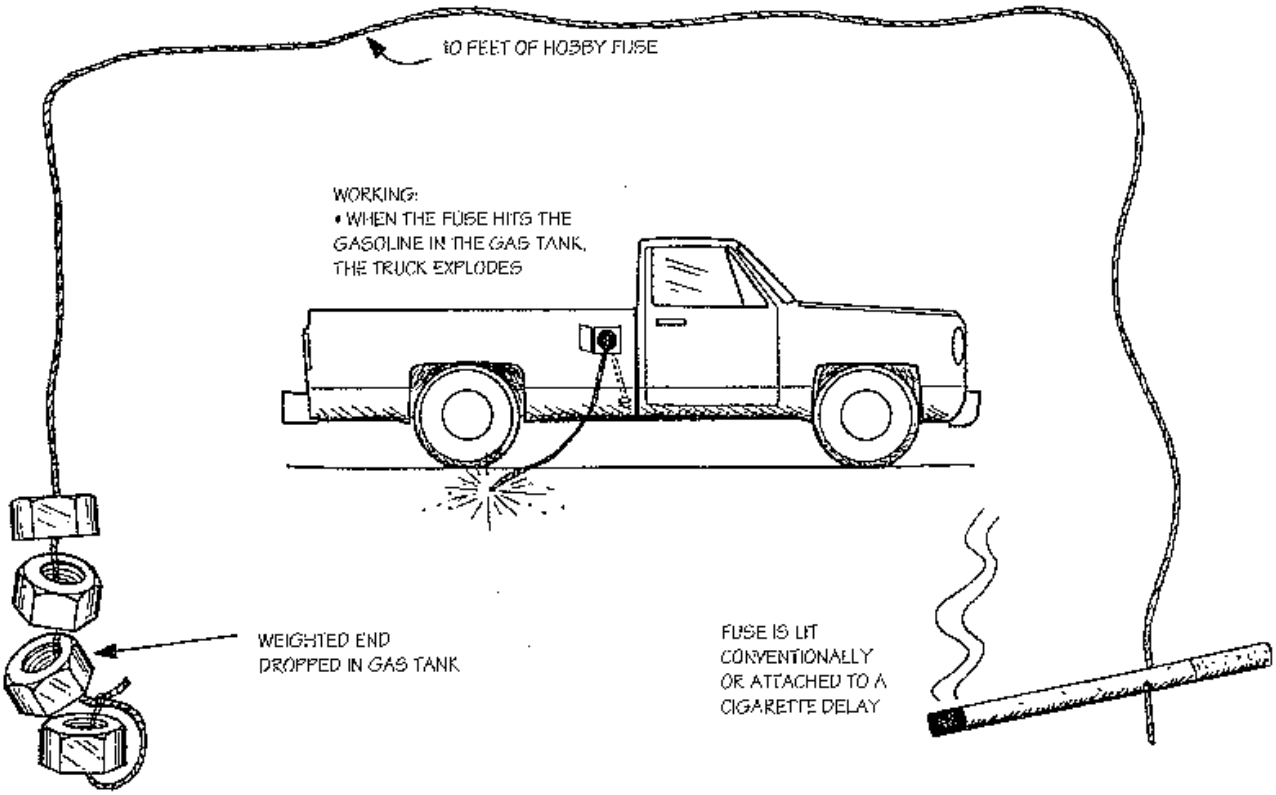
When the police bomb technicians arrive on the scene, they should best decide how to attack the suspected vehicle .The vehicle should be viewed through high-powered binoculars or, even better, a spotter's scope or telescope .

The public should never be allowed to watch the bomb squad at work or learn the techniques employed to render a device safe .Why ? Because the bomber himself may be in the crowd watching and learning how to circumvent the render-safe procedures employed by the technicians .
Looking through the spotter's scope, the bomb technician is looking for anything out of the norm, such as visible wiring protruding through the vehicle, an open trunk, hood, door, etc .But beware : a visible bomb may only be bait for a second device triggered by other means .
After the suspected car has been viewed from a distance, the decision must be made to approach the vehicle .if your department is lucky enough to have a robot equipped for this, you are at an advantage .if not, then you should consider calling a neighboring department that does .
A poor man's robot could be constructed from a toy remote-control car and a citizen's band radio equipped with a strong linear amplifier .The CB is strapped to the toy car .The car approaches the suspected vehicle and touches it .
If it does not explode, the CB mic is keyed (also via remote control) .The linear amp puts out an extremely high level of wattage .This should detonate any electric blasting cap used in the bomb .The toy car must be able to receive its signals from the bomb technician from several hundred feet away .
From this point, the car could be approached by the bomb technician .He should be in a full bomb-resistant suit and shield .This must be done with extreme caution .He should look all around the vehicle for wiring as well as underneath it .Some bomb techs use a mirror first, which is a good idea .
Always consider the possibility of simply letting the car blow up .You never see firemen rushing into a burning building unless they are positive they can win the battle .Your job is to protect human life at all costs, including your own .
Property can be replaced-people cannot .
Frequently, the news tells of a car full of explosives being placed along the road where the target habitually drives .
The bomb is detonated when the target drives by .These devices can be placed in many locations along the route and are extremely hard to detect ahead of time .
When a VIP travels through a city, security personnel arrive ahead of time to minimize these risks .This usually entails removing mailboxes, welding shut manhole covers, and towing away abandoned vehicles .
So what does the future hold ? Terrorists, many of whom employ electrical and chemical engineers, will almost certainly keep abreast of advances in microcircuitry, impossible-to-detect liquid explosives, biological and nuclear possibilities, etc .The bomb technician would be wise to keep up with these advances also .
Once again, the author makes no claims of authority nor has the proper credentials or training to give up-to-date training or information on explosive ordnance recognition or disposal .The information in this book is presented for academic study only !
END OF CAR BOMB RECOGNITION GUIDE BOOK (TEXT) .


ALLIGATOR CLIP TO GROUND—I.E., CAR FRAME, ENGINE BOLT, ETC.
HEAVY-GAUGE INSULATED WIRE LEADS
1/8" BORE HOLE IN PIPE CAP
ALLIGATOR CLIP TO POSITIVE TERMINAL ON COIL
TO DISTRIBUTOR
IRON PIPE BOMB WITH FLASHBULB AND BLACK POWDER FILLER
COIL IN AUTOMOBILE
METHOD I
TO BATTERY
HEAVY-GAUGE INSULATED WIRE LEADS
INSULATED ALLIGATOR CLIPS
STARTER SOLENOID IN AUTOMOBILE
PLASTIC PVC PIPE BOMB WITH FLASHBULB IGNITOR AND BLACK POWDER FILLER
PIPE AND CAPS ARE DRILLED. CAPS ARE THEN RIVETED TO PIPE.
METHOD II

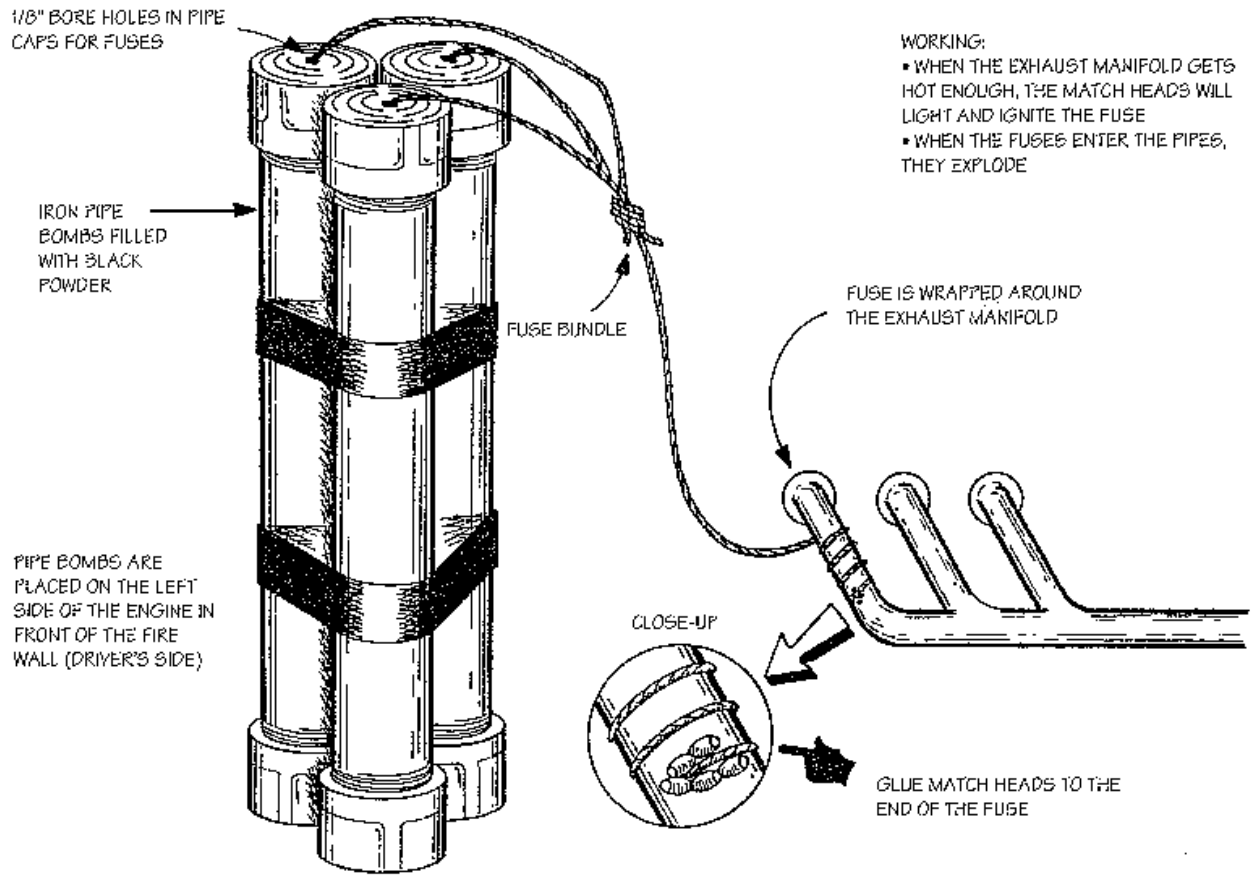
UNDER THE HOOD STANDARD CAR BOMB HOOK-UP METHODS

IMPROVISED CAR BOMB NO. 1


10 FEET OF HOBBY FUSE
WORKING:
• WHEN THE FUSE HITS THE GASOLINE IN THE GAS TANK, THE TRUCK EXPLODES
WEIGHTED END DROPPED IN GAS TANK
FUSE IS LIT CONVENTIONALLY OR ATTACHED TO A CIGARETTE DELAY

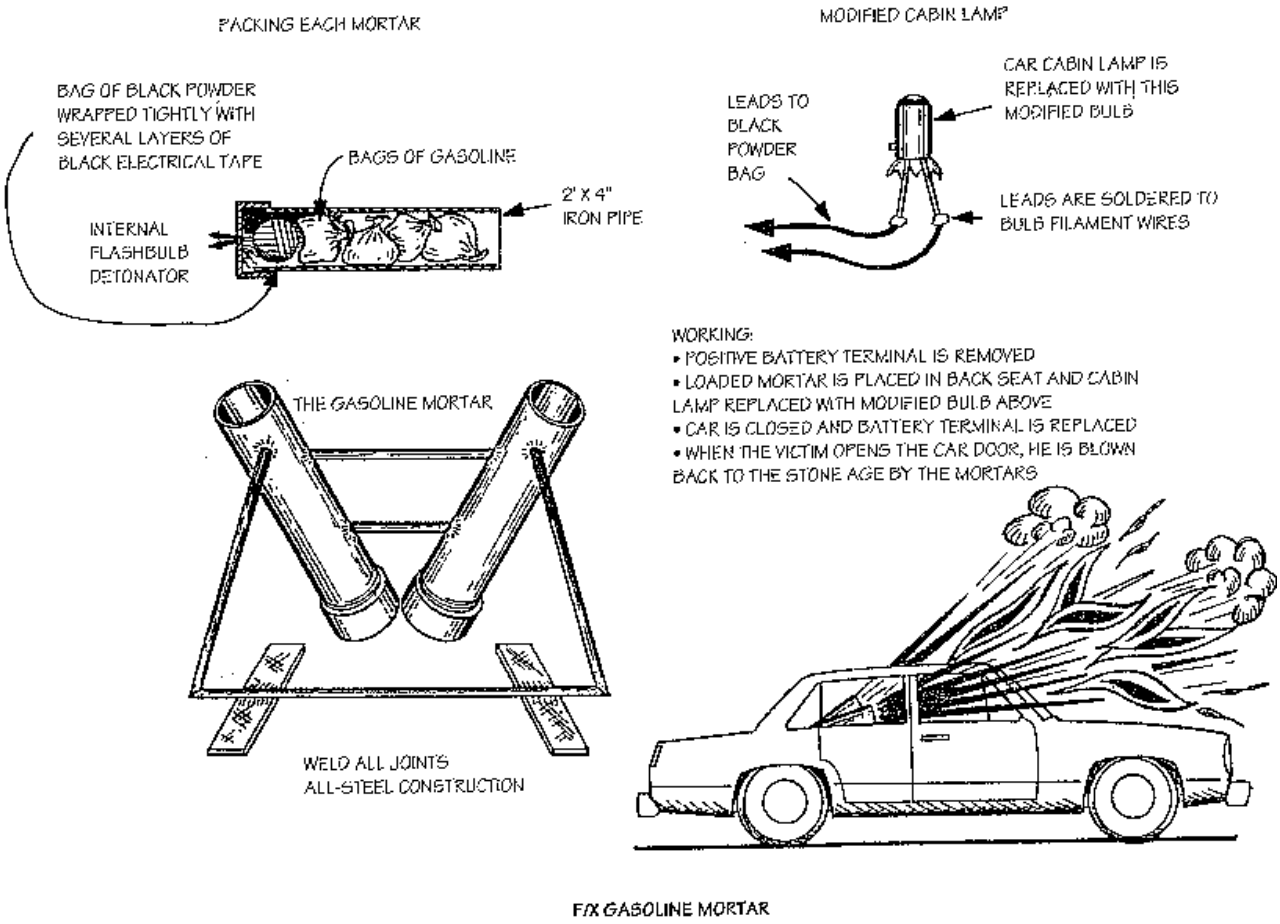
WEIGHTED FUSE DEVICE

IMPROVISED CAR BOMB NO. 2


1/8" BORE HOLES IN PIPE CAPS FOR FUSES
IRON PIPE BOMBS FILLED WITH BLACK POWDER
PIPE BOMBS ARE PLACED ON THE LEFT SIDE OF THE ENGINE IN FRONT OF THE FIRE WALL (DRIVER'S SIDE)
FUSE BUNDLE
WORKING:
• WHEN THE EXHAUST MANIFOLD GETS HOT ENOUGH, THE MATCH HEADS WILL LIGHT AND IGNITE THE FUSE
• WHEN THE FUSES ENTER THE PIPES, THEY EXPLODE
FUSE IS WRAPPED AROUND THE EXHAUST MANIFOLD
CLOSE-UP
GLUE MATCH HEADS TO THE END OF THE FUSE

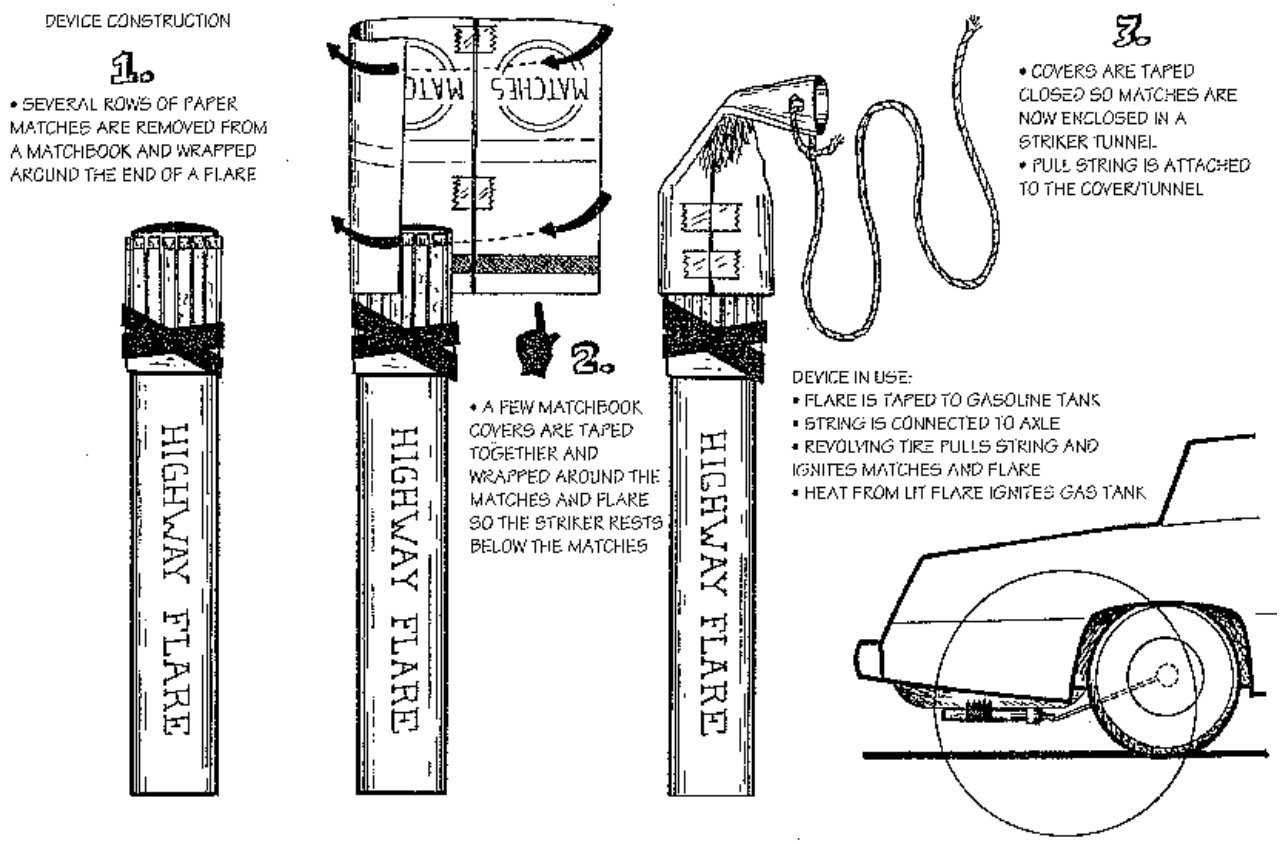
MANIFOLD FUSE IGNITION

IMPROVISED CAR BOMB NO. 3


PACKING EACH MORTAR
BAG OF BLACK POWDER WRAPPED TIGHTLY WITH SEVERAL LAYERS OF BLACK ELECTRICAL TAPE
BAGS OF GASOLINE
2" X 4" IRON PIPE
INTERNAL FLASHBULB DETONATOR
MODIFIED CABIN LAMP
CAR CABIN LAMP IS REPLACED WITH THIS MODIFIED BULB
LEADS TO BLACK POWDER BAG
LEADS ARE SOLDERED TO BULB FILAMENT WIRES
THE GASOLINE MORTAR
WELD ALL JOINTS ALL-STEEL CONSTRUCTION
WORKING:
• POSITIVE BATTERY TERMINAL IS REMOVED
• LOADED MORTAR IS PLACED IN BACK SEAT AND CABIN LAMP REPLACED WITH MODIFIED BULB ABOVE
• CAR IS CLOSED AND BATTERY TERMINAL IS REPLACED
• WHEN THE VICTIM OPENS THE CAR DOOR, HE IS BLOWN BACK TO THE STONE AGE BY THE MORTARS

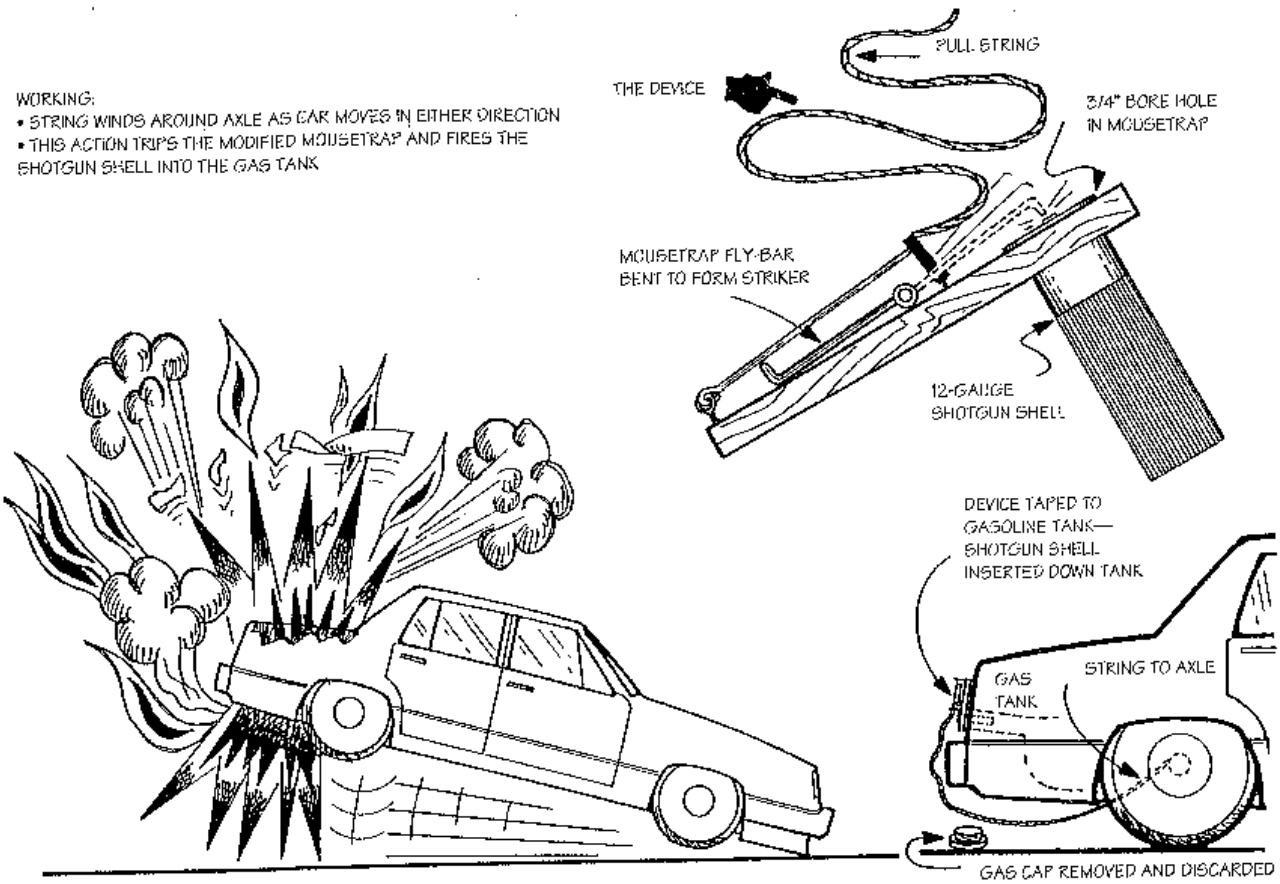
F/X GASOLINE MORTAR

IMPROVISED CAR BOMB NO. 4


DEVICE CONSTRUCTION
1.
• SEVERAL ROWS OF PAPER MATCHES ARE REMOVED FROM A MATCHBOOK AND WRAPPED AROUND THE END OF A FLARE
HIGHWAY FLARE
MATCHES
HIGHWAY FLARE
2.
• A FEW MATCHBOOK COVERS ARE TAPED TOGETHER AND WRAPPED AROUND THE MATCHES AND FLARE SO THE STRIKER RESTS BELOW THE MATCHES
HIGHWAY FLARE
3.
• COVERS ARE TAPED CLOSED SO MATCHES ARE NOW ENCLOSED IN A STRIKER TUNNEL
• PULL STRING IS ATTACHED TO THE COVER/TUNNEL
DEVICE IN USE:
• FLARE IS TAPED TO GASOLINE TANK
• STRING IS CONNECTED TO AXLE
• REVOLVING TIRE PULLS STRING AND IGNITES MATCHES AND FLARE
• HEAT FROM LIT FLARE IGNITES GAS TANK

FLARE IGNITION DEVICE

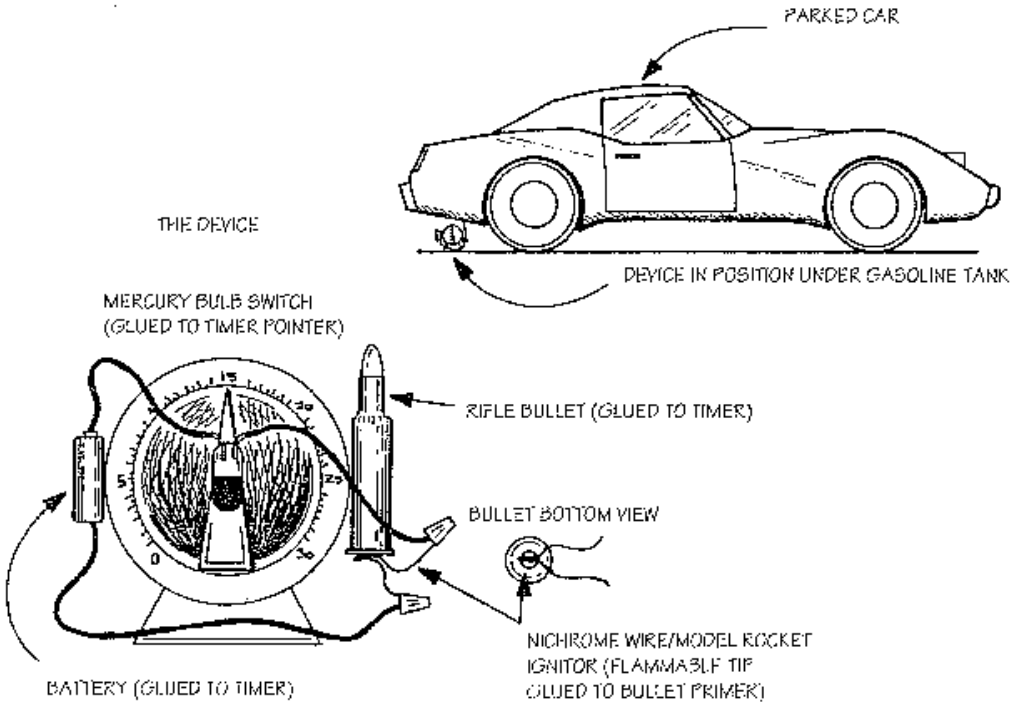
IMPROVISED CAR BOMB NO. 5


WORKING:
• STRING WINDS AROUND AXLE AS CAR MOVES IN EITHER DIRECTION
• THIS ACTION TRIPS THE MODIFIED MOUSETRAP AND FIRES THE SHOTGUN SHELL INTO THE GAS TANK
PULL STRING
THE DEVICE
3/4" BORE HOLE IN MOUSETRAP
MOUSETRAP FLY-BAR BENT TO FORM STRIKER
12-GAUGE SHOTGUN SHELL
DEVICE TAPED TO GASOLINE TANK— SHOTGUN SHELL INSERTED DOWN TANK
STRING TO AXLE
GAS TANK
GAS CAP REMOVED AND DISCARDED

SHOTGUN SHELL DEVICE

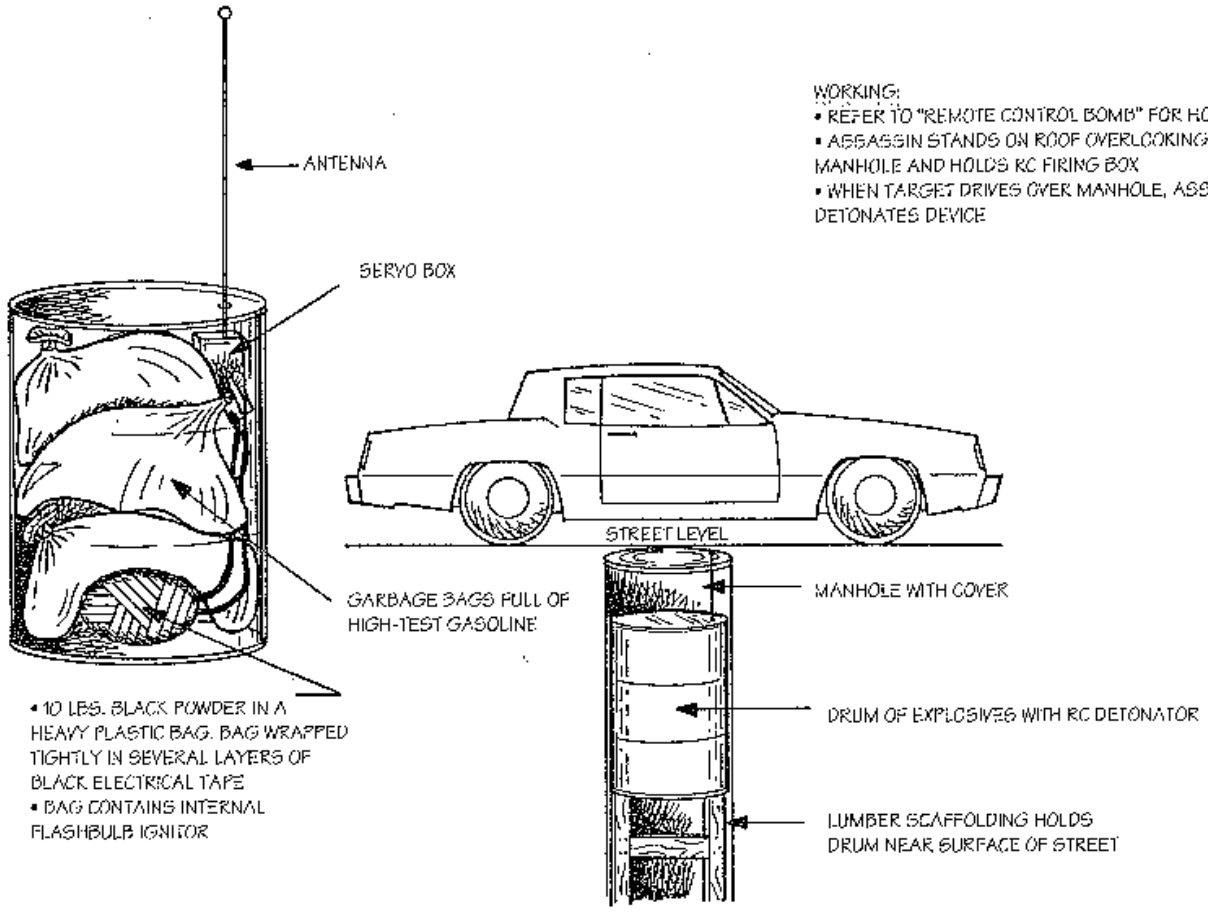
IMPROVISED CAR BOMB NO. 6

WORKING:
• TIMER COUNTS DOWN AND TILTS MERCURY SWITCH
• THIS ACTION COMPLETES THE ELECTRICAL CIRCUIT AND IGNITES THE MODEL ROCKET IGNITOR
• THE FLAME HEATS UP THE BULLET PRIMER AND FIRES BULLET INTO THE CAR'S GAS TANK
• THE GASOLINE TANK EXPLODES


PARKED CAR
THE DEVICE
DEVICE IN POSITION UNDER GASOLINE TANK
MERCURY BULB SWITCH
(GLUED TO TIMER POINTER)
RIFLE BULLET (GLUED TO TIMER)
BULLET BOTTOM VIEW
NICHROME WIRE/MODEL ROCKET IGNITOR (FLAMMABLE TIP GLUED TO BULLET PRIMER)
BATTERY (GLUED TO TIMER)

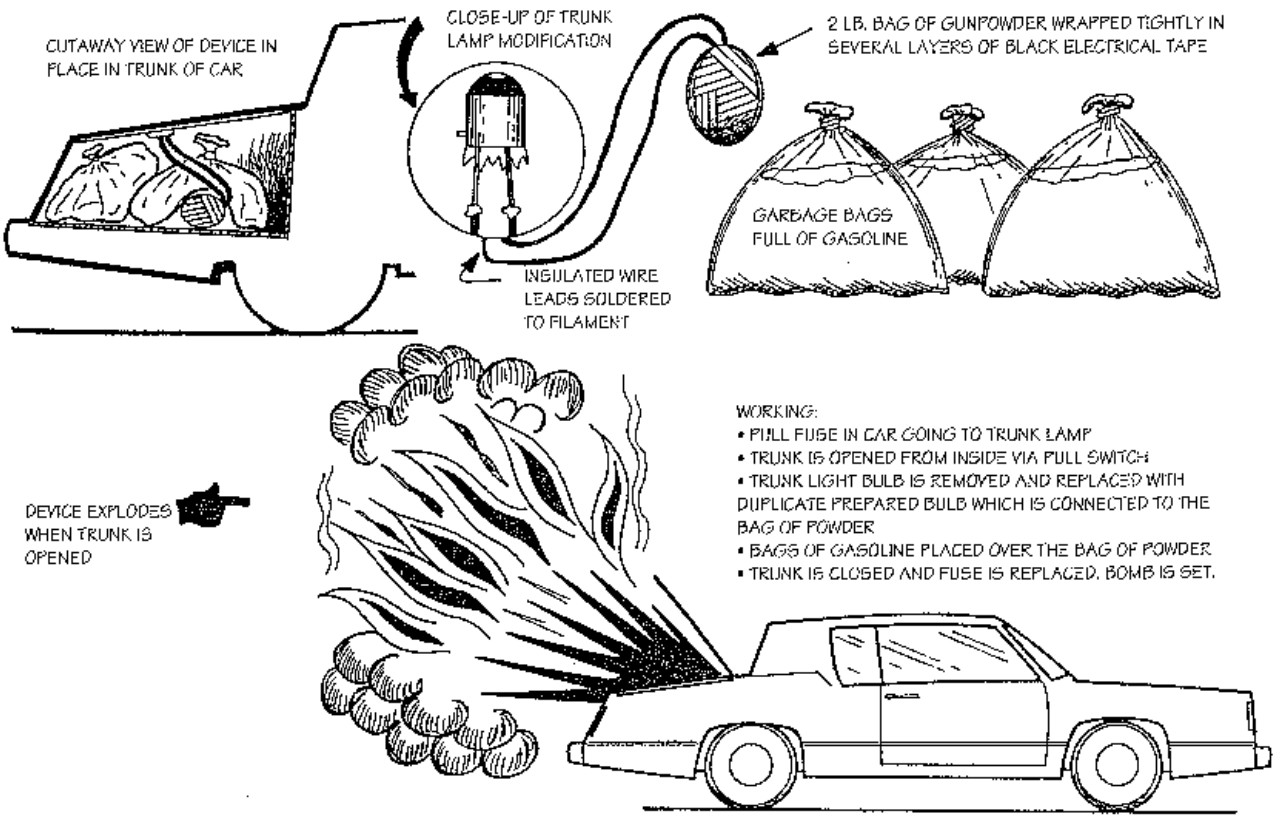
RIFLE BULLET TIMED-DELAY DEVICE

IMPROVISED CAR BOMB NO. 7


ANTENNA
SERVO BOX
GARBAGE BAGS FULL OF HIGH-TEST GASOLINE
• 10 LBS. BLACK POWDER IN A HEAVY PLASTIC BAG. BAG WRAPPED TIGHTLY IN SEVERAL LAYERS OF BLACK ELECTRICAL TAPE
• BAG CONTAINS INTERNAL FLASHBULB IGNITOR
STREET LEVEL
MANHOLE WITH COVER
DRUM OF EXPLOSIVES WITH RC DETONATOR
LUMBER SCAFFOLDING HOLDS DRUM NEAR SURFACE OF STREET
WORKING:
• REFER TO "REMOTE CONTROL BOMB" FOR HOOKUP
• ASSASSIN STANDS ON ROOF OVERLOOKING MANHOLE AND HOLDS RC FIRING BOX
• WHEN TARGET DRIVES OVER MANHOLE, ASSASSIN DETONATES DEVICE

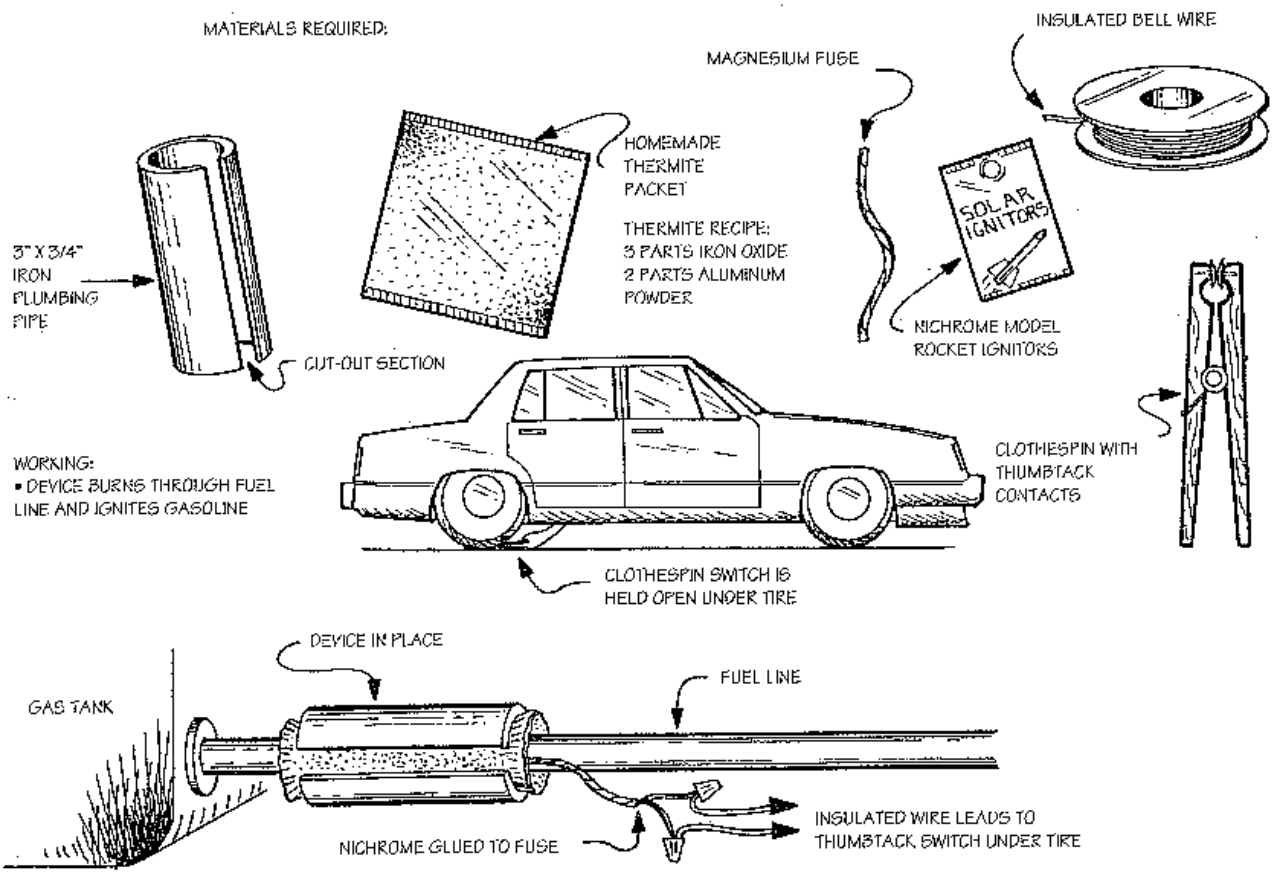
MANHOLE DEVICE

IMPROVISED CAR BOMB NO. 8


CUTAWAY VIEW OF DEVICE IN PLACE IN TRUNK OF CAR
CLOSE-UP OF TRUNK LAMP MODIFICATION
2 LB. BAG OF GUNPOWDER WRAPPED TIGHTLY IN SEVERAL LAYERS OF BLACK ELECTRICAL TAPE
GARBAGE BAGS FULL OF GASOLINE
INSULATED WIRE LEADS SOLDERED TO FILAMENT
DEVICE EXPLODES WHEN TRUNK IS OPENED
WORKING:
• PULL FUSE IN CAR GOING TO TRUNK LAMP
• TRUNK IS OPENED FROM INSIDE VIA PULL SWITCH
• TRUNK LIGHT BULB IS REMOVED AND REPLACED WITH DUPLICATE PREPARED BULB WHICH IS CONNECTED TO THE BAG OF POWDER
• BAGS OF GASOLINE PLACED OVER THE BAG OF POWDER
• TRUNK IS CLOSED AND FUSE IS REPLACED. BOMB IS SET.

CHARLIE VARRICK REVISITED (TRUNK BOMB)

IMPROVISED CAR BOMB NO. 9

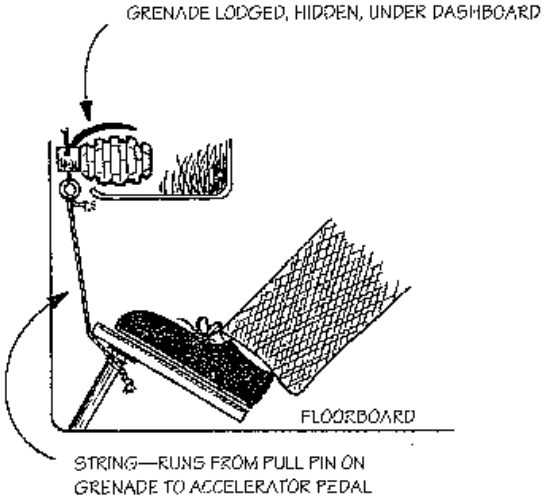


THERMITE DEVICE

IMPROVISED CAR BOMB NO. 10

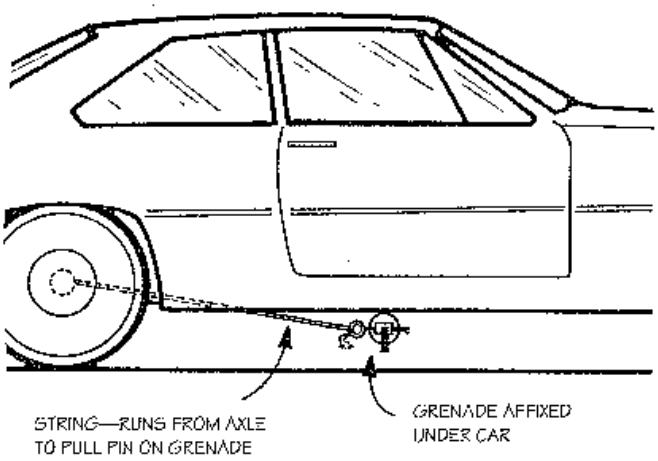
METHOD ONE

WORKING:
VICTIM PUSHES DOWN ACCELERATOR.
PIN IS PULLED ON GRENADE.
GRENADE SPOON IS RELEASED AND
GRENADE EXPLODES



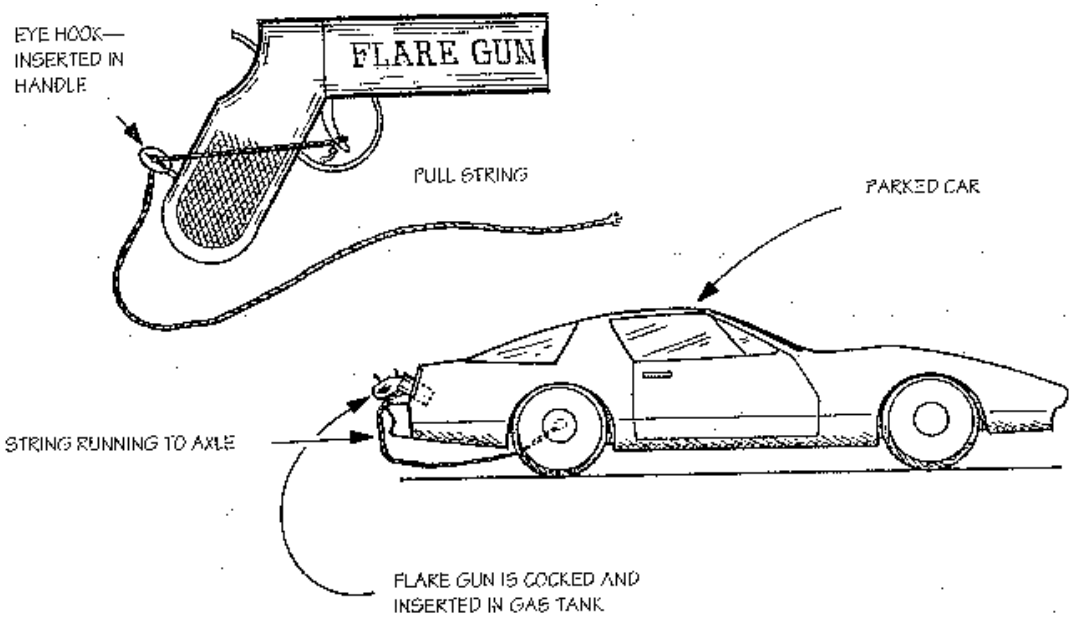
METHOD TWO

WORKING:
AS CAR MOVES IN EITHER
DIRECTION, THE STRING WINDS
AROUND THE AXLE AND PULLS THE
PIN ON THE GRENADE. THE SPOON
EJECTS AUTOMATICALLY AND THE
GRENADE EXPLODES



GRENADE TRICKS

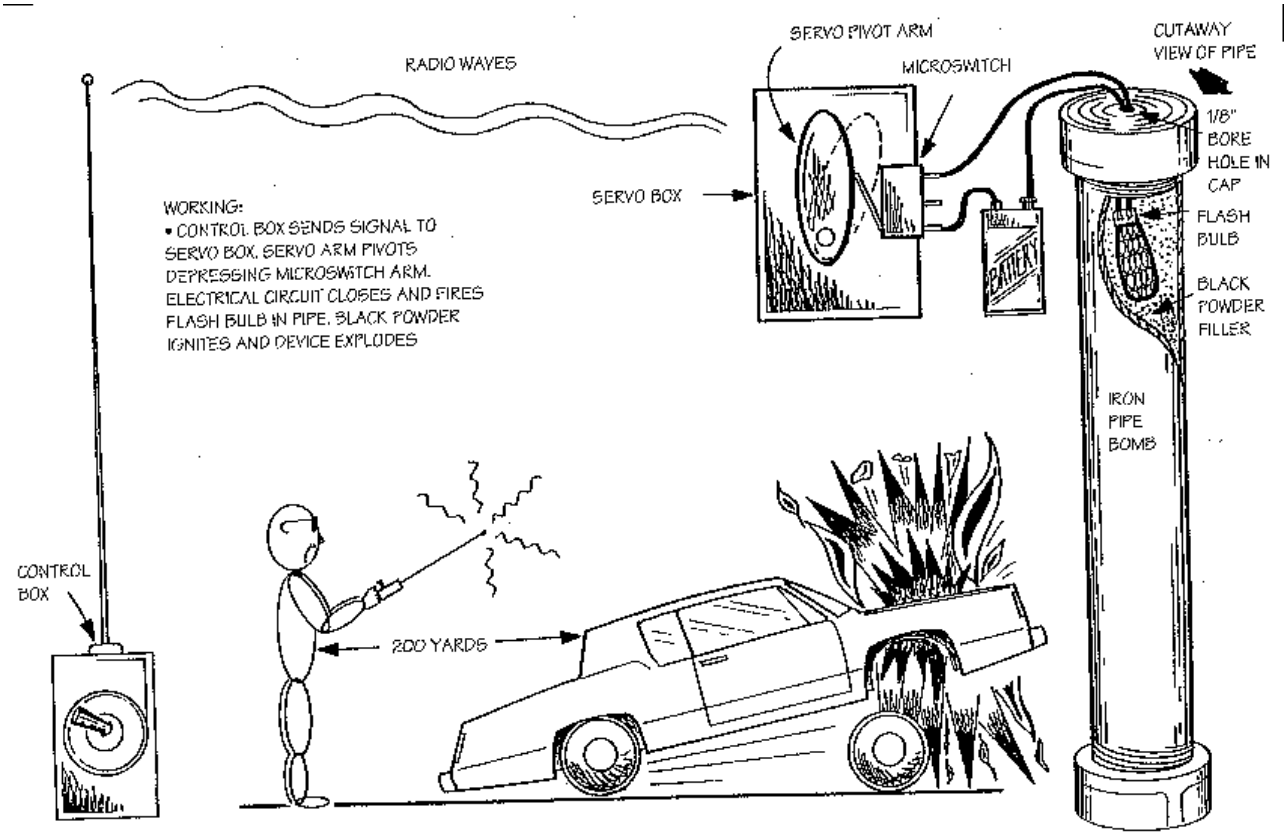
IMPROVISED CAR BOMB NO. 11



WORKING:
• STRING WINDS AROUND AXLE AS CAR MOVES IN EITHER DIRECTION. THIS ACTION PULLS THE TRIGGER ON THE FLARE GUN AND FIRES IT INTO THE GAS TANK

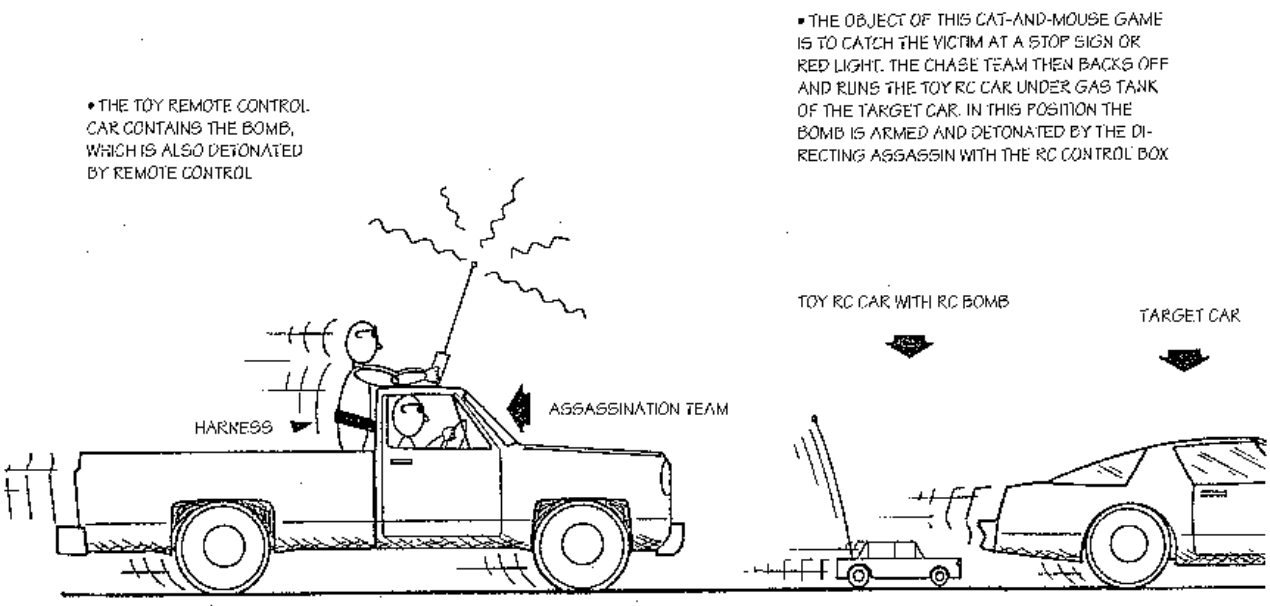
FLARE GUN IGNITION

IMPROVISED CAR BOMB NO. 12


SERVO PIVOT ARM
CUTAWAY VIEW OF PIPE
RADIO WAVES
MICROSWITCH
1/8" BORE HOLE IN CAP
SERVO BOX
WORKING:
• CONTROL BOX SENDS SIGNAL TO SERVO BOX. SERVO ARM PIVOTS DEPRESSING MICROSWITCH ARM. ELECTRICAL CIRCUIT CLOSES AND FIRES FLASH BULB IN PIPE. BLACK POWDER IGNITES AND DEVICE EXPLODES
BATTERY
FLASH BULB
BLACK POWDER FILLER
IRON PIPE BOMB
CONTROL BOX
200 YARDS

REMOTE CONTROL BOMB

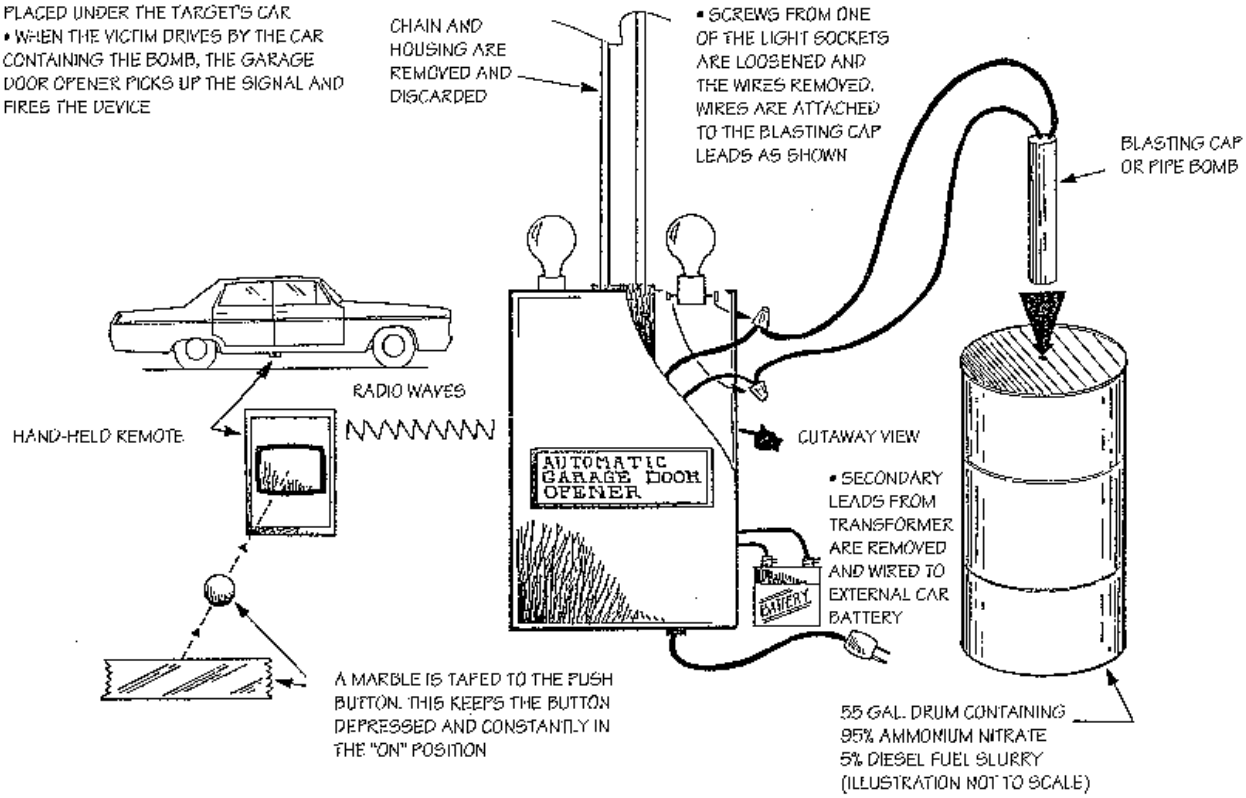
IMPROVISED CAR BOMB NO. 13


• THE TOY REMOTE CONTROL CAR CONTAINS THE BOMB, WHICH IS ALSO DETONATED BY REMOTE CONTROL
• THE OBJECT OF THIS CAT-AND-MOUSE GAME IS TO CATCH THE VICTIM AT A STOP SIGN OR RED LIGHT. THE CHASE TEAM THEN BACKS OFF AND RUNS THE TOY RC CAR UNDER GAS TANK OF THE TARGET CAR. IN THIS POSITION THE BOMB IS ARMED AND DETONATED BY THE DIRECTING ASSASSIN WITH THE RC CONTROL BOX
TOY RC CAR WITH RC BOMB
TARGET CAR
HARNESS
ASSASSINATION TEAM

TOY REMOTE CONTROL DEVICE

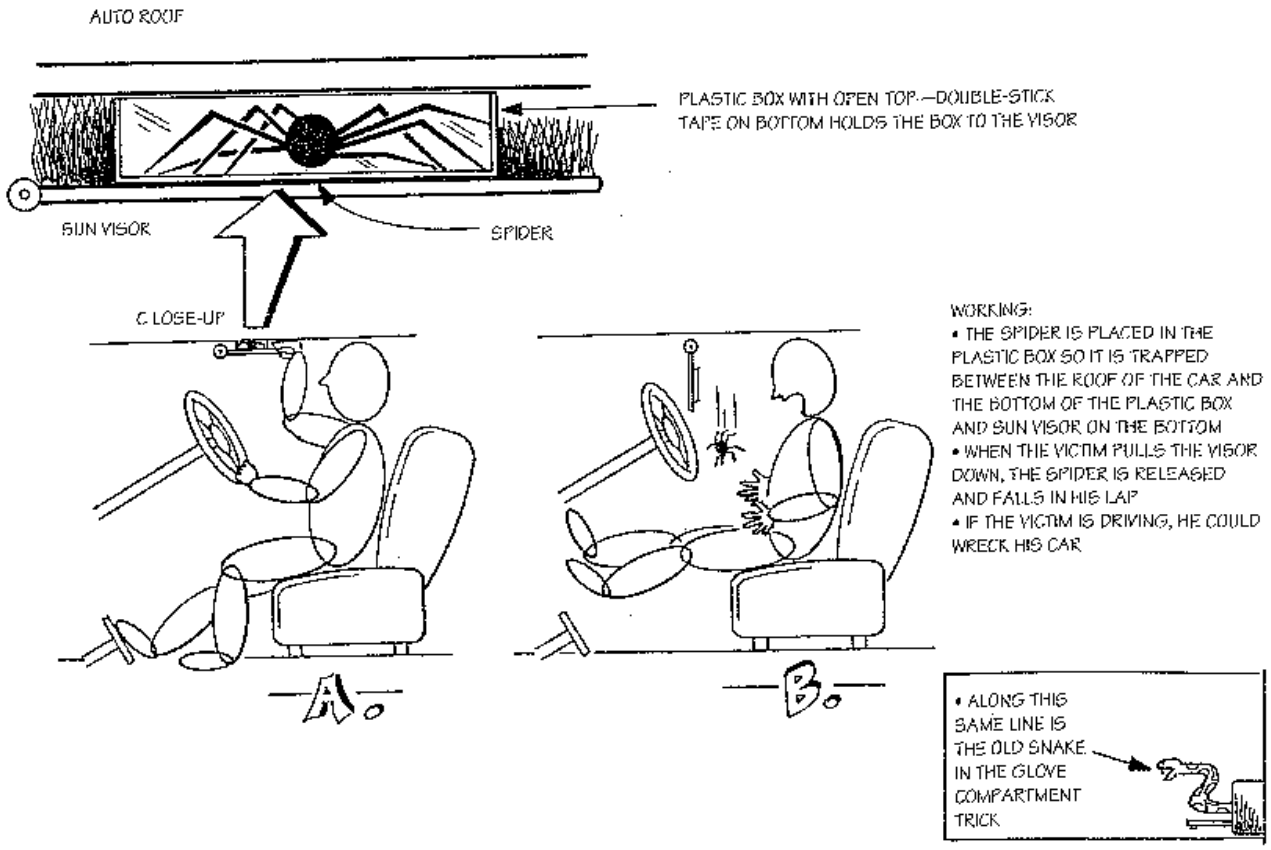
IMPROVISED CAR BOMB NO. 14

WORKING:
• GARAGE DOOR OPENER AND THE BOMB HIDDEN IN A CAR ARE PLACED ALONG THE ROAD WHERE THE VICTIM DRIVES DAILY
• PREPARED HAND-HELD REMOTE IS PLACED UNDER THE TARGET'S CAR
• WHEN THE VICTIM DRIVES BY THE CAR CONTAINING THE BOMB, THE GARAGE DOOR OPENER PICKS UP THE SIGNAL AND FIRES THE DEVICE


CHAIN AND HOUSING ARE REMOVED AND DISCARDED
• SCREWS FROM ONE OF THE LIGHT SOCKETS ARE LOOSENED AND THE WIRES REMOVED. WIRES ARE ATTACHED TO THE BLASTING CAP LEADS AS SHOWN
BLASTING CAP OR PIPE BOMB
RADIO WAVES
HAND-HELD REMOTE
AUTOMATIC GARAGE DOOR OPENER
CUTAWAY VIEW
• SECONDARY LEADS FROM TRANSFORMER ARE REMOVED AND WIRED TO EXTERNAL CAR BATTERY
BATTERY
A MARBLE IS TAPED TO THE PUSH BUTTON. THIS KEEPS THE BUTTON DEPRESSED AND CONSTANTLY IN THE "ON" POSITION
55 GAL. DRUM CONTAINING 95% AMMONIUM NITRATE 5% DIESEL FUEL SLURRY
(ILLUSTRATION NOT TO SCALE)

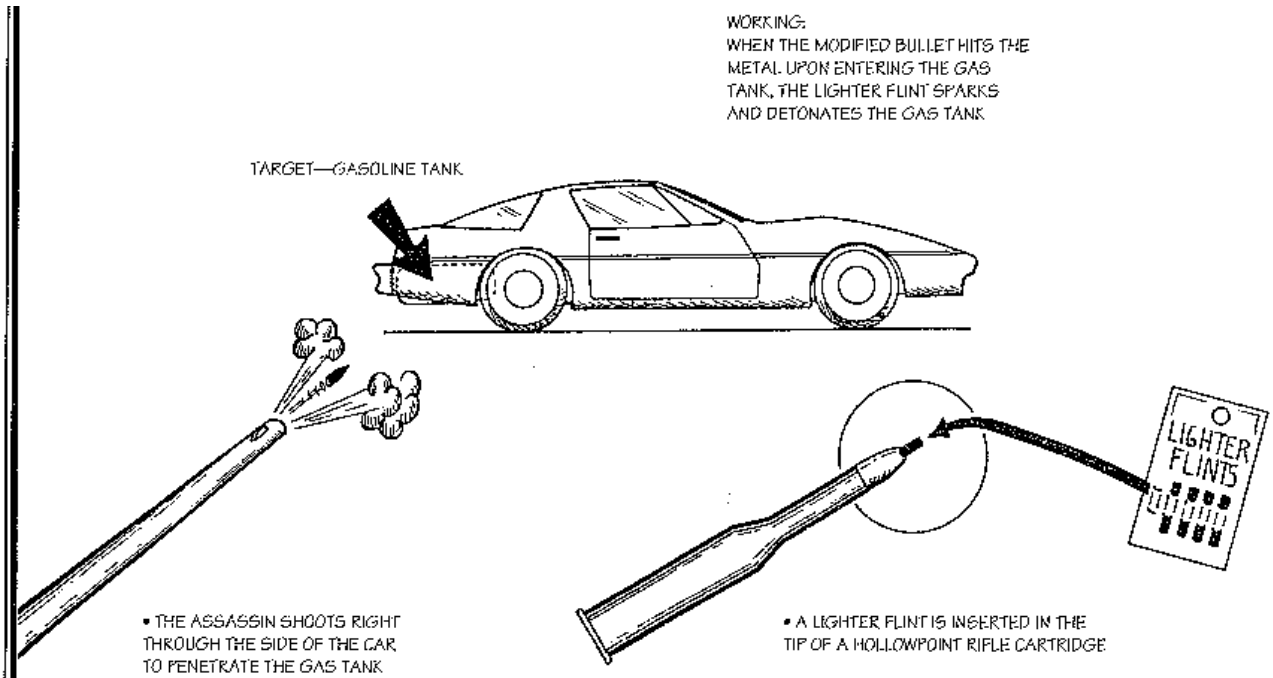
GARAGE DOOR OPENER BOMB

IMPROVISED CAR BOMB NO. 15


AUTO ROOF
PLASTIC BOX WITH OPEN TOP.—DOUBLE-STICK TAPE ON BOTTOM HOLDS THE BOX TO THE VISOR
SUN VISOR
SPIDER
CLOSE-UP
A
B
WORKING:
• THE SPIDER IS PLACED IN THE PLASTIC BOX SO IT IS TRAPPED BETWEEN THE ROOF OF THE CAR AND THE BOTTOM OF THE PLASTIC BOX AND SUN VISOR ON THE BOTTOM
• WHEN THE VICTIM PULLS THE VISOR DOWN, THE SPIDER IS RELEASED AND FALLS IN HIS LAP
• IF THE VICTIM IS DRIVING, HE COULD WRECK HIS CAR
• ALONG THIS SAME LINE IS THE OLD SNAKE IN THE GLOVE COMPARTMENT TRICK

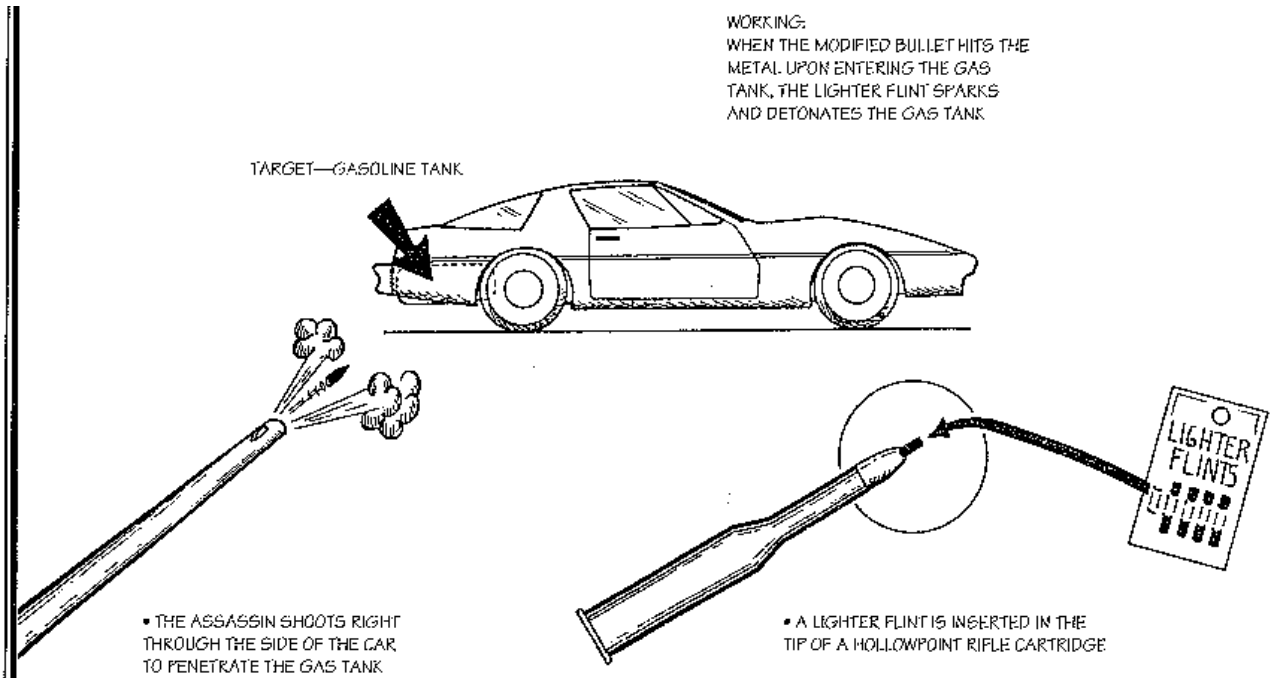
POISONOUS INSECT TRAP

IMPROVISED CAR BOMB NO. 16


WORKING:
WHEN THE MODIFIED BULLET HITS THE METAL UPON ENTERING THE GAS TANK, THE LIGHTER FLINT SPARKS AND DETONATES THE GAS TANK
TARGET—GASOLINE TANK
LIGHTER FLINTS
• THE ASSASSIN SHOOTS RIGHT THROUGH THE SIDE OF THE CAR TO PENETRATE THE GAS TANK
• A LIGHTER FLINT IS INSERTED IN THE TIP OF A HOLLOWPOINT RIFLE CARTRIDGE

LONG-RANGE RIFLE DETONATION

IMPROVISED CAR BOMB NO. 17


WORKING:
WHEN THE MODIFIED BULLET HITS THE METAL UPON ENTERING THE GAS TANK, THE LIGHTER FLINT SPARKS AND DETONATES THE GAS TANK
TARGET—GASOLINE TANK
LIGHTER FLINTS
• THE ASSASSIN SHOOTS RIGHT THROUGH THE SIDE OF THE CAR TO PENETRATE THE GAS TANK
• A LIGHTER FLINT IS INSERTED IN THE TIP OF A HOLLOWPOINT RIFLE CARTRIDGE

LONG-RANGE RIFLE DETONATION

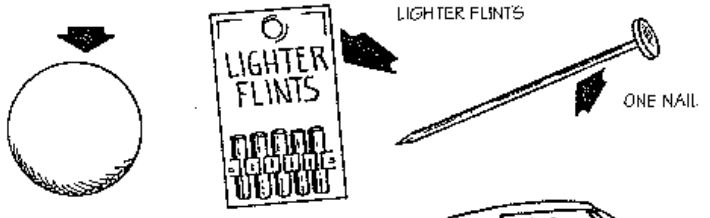
IMPROVISED CAR BOMB NO. 17

MATERIALS:

SOLID LITTLE RUBBER BALL

SEVERAL PACKS OF LIGHTER FLINTS

ONE NAIL

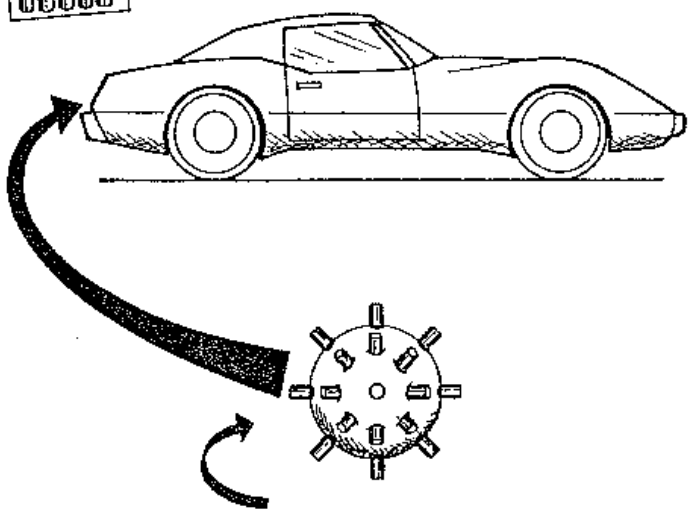


OPTIONS:

- FOR A DELAY, THE DEVICE IS ENCLOSED IN A BALLOON. THE GASOLINE WILL EVENTUALLY EAT THROUGH THE BALLOON AND RELEASE THE BALL.
- YET ANOTHER DELAY WOULD BE TO AFFIX THE DEVICE TOP TO THE INSIDE OF THE GAS CAP WITH A HEAVY BEESWAX PELLET. HEAT, SUCH AS A SUMMER MIDDAY HEAT, WILL MELT THE WAX AND THE DEVICE WILL DROP IN THE TANK.

CONSTRUCTION AND WORKING:

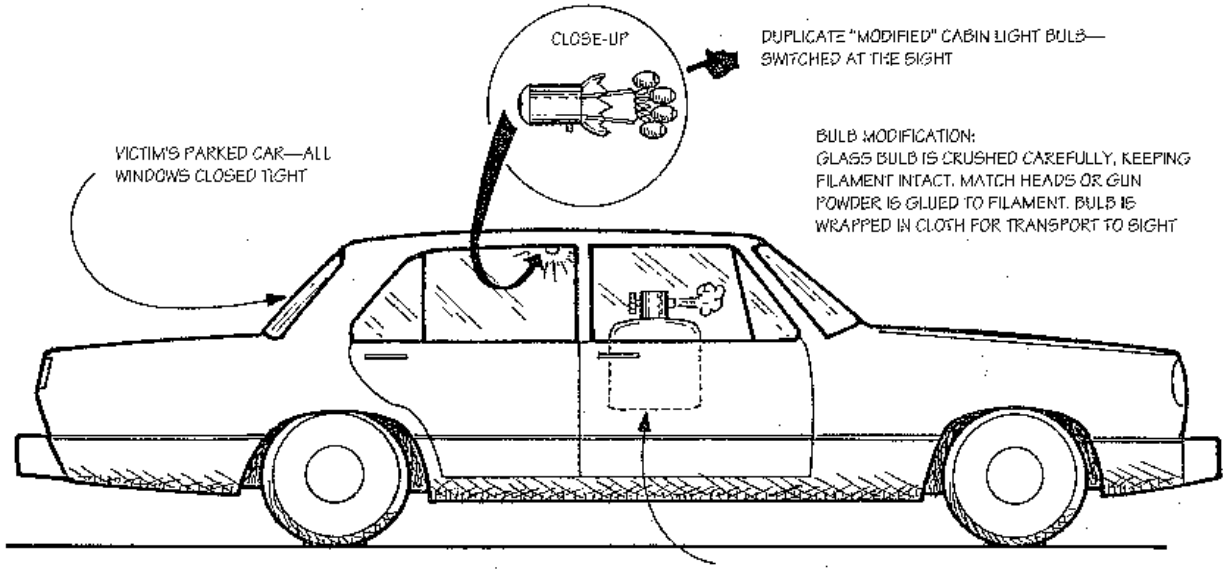
- HOLES ARE POKED ALL AROUND THE BALL WITH THE NAIL.
- LIGHTER FLINTS ARE INSERTED IN THESE HOLES SO THEY PROTRUDE SLIGHTLY.
- DEVICE IS INSERTED IN THE ENEMY GASOLINE TANK. THE BALL WILL FALL TO THE BOTTOM OF THE TANK.
- WHEN THE TANK IS ALMOST EMPTY, THE BALL WILL BEGIN BOUNCING AROUND. THE FLINT WILL SPARK ON THE SIDE OF THE TANK AND IGNITE THE GAS VAPORS. THE GAS TANK EXPLODES.



FINISHED DEVICE (ACTUAL SIZE)

BOUNCER

IMPROVISED CAR BOMB NO. 18

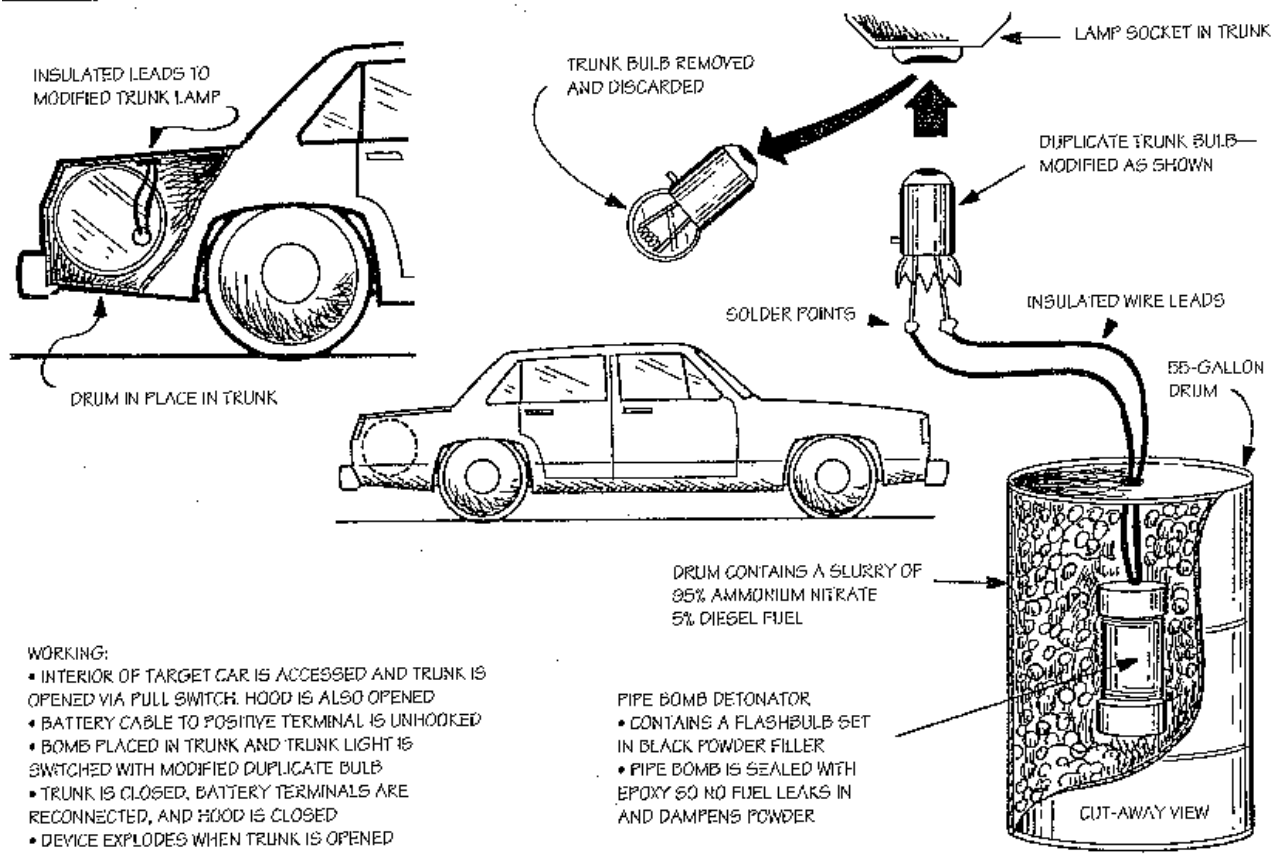

CLOSE-UP
DUPLICATE "MODIFIED" CABIN LIGHT BULB—SWITCHED AT THE SIGHT
VICTIM'S PARKED CAR—ALL WINDOWS CLOSED TIGHT
BULB MODIFICATION:
GLASS BULB IS CRUSHED CAREFULLY, KEEPING FILAMENT INTACT. MATCH HEADS OR GUN POWDER IS GLUED TO FILAMENT. BULB IS WRAPPED IN CLOTH FOR TRANSPORT TO SIGHT
FULL PROPANE BOTTLE—NOZZLE OPENED FOR SLOW LEAK

WORKING:

- ACCESS TO AUTOMOBILE INTERIOR IS GAINED AND HOOK IS OPENED VIA INTERNAL PULL SWITCH
- HOOD IS OPENED AND POSITIVE BATTERY TERMINAL REMOVED. ALL ELECTRICAL POWER TO CAR SHOULD NOW BE "OFF"
- CABIN LIGHT IN INTERIOR OF VEHICLE IS SWITCHED WITH THE MODIFIED BULB
- VALVE ON THE PROPANE TANK IS OPENED AND SET FOR A SLOW LEAK IF THE CAR WON'T BE OPENED OVERNIGHT
- CAR IS CLOSED BACK UP, THE BATTERY TERMINAL IS RECONNECTED, AND THE HOOD IS CLOSED
- WHEN VICTIM OPENS THE CAR, THE MODIFIED BULB IGNITES THE CABIN FULL OF FLAMMABLE GAS AND CAR EXPLODES

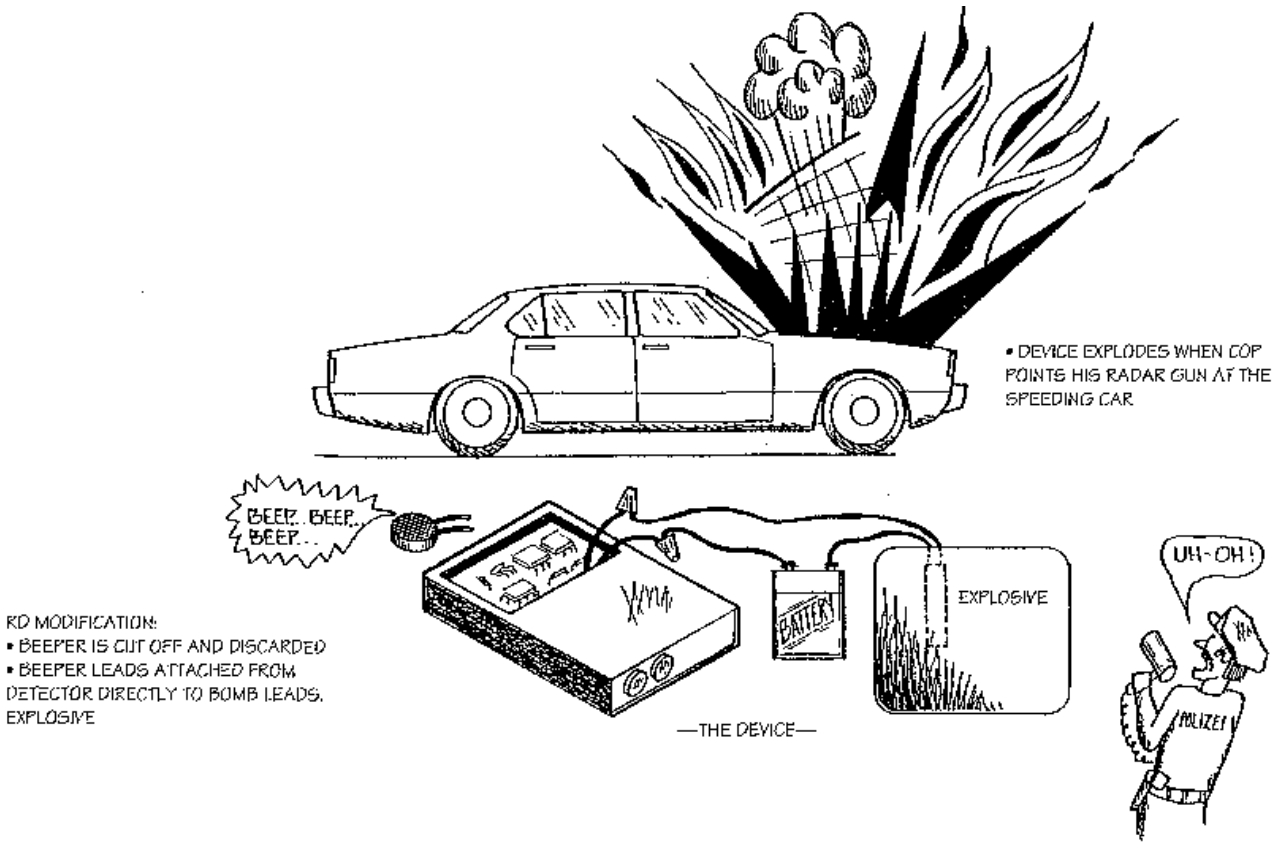
FLAMMABLE VAPOR TECHNIQUE

IMPROVISED CAR BOMB NO. 19


INSULATED LEADS TO MODIFIED TRUNK LAMP
DRUM IN PLACE IN TRUNK
TRUNK BULB REMOVED AND DISCARDED
LAMP SOCKET IN TRUNK
DUPLICATE TRUNK BULB— MODIFIED AS SHOWN
SOLDER POINTS
INSULATED WIRE LEADS
55-GALLON DRUM
DRUM CONTAINS A SLURRY OF 95% AMMONIUM NITRATE 5% DIESEL FUEL
PIPE BOMB DETONATOR
• CONTAINS A FLASHBULB SET IN BLACK POWDER FILLER
• PIPE BOMB IS SEALED WITH EPOXY SO NO FUEL LEAKS IN AND DAMPENS POWDER
CUT-AWAY VIEW
WORKING:
• INTERIOR OF TARGET CAR IS ACCESSED AND TRUNK IS OPENED VIA PULL SWITCH. HOOD IS ALSO OPENED
• BATTERY CABLE TO POSITIVE TERMINAL IS UNHOOKED
• BOMB PLACED IN TRUNK AND TRUNK LIGHT IS SWITCHED WITH MODIFIED DUPLICATE BULB
• TRUNK IS CLOSED, BATTERY TERMINALS ARE RECONNECTED, AND HOOD IS CLOSED
• DEVICE EXPLODES WHEN TRUNK IS OPENED

AMMONIUM NITRATE TRUNK BOMB

IMPROVISED CAR BOMB NO. 20



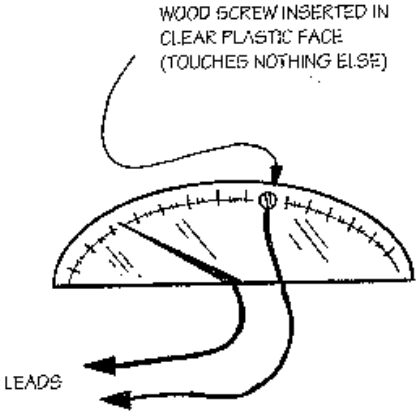
RADAR DETECTOR BOMB

IMPROVISED CAR BOMB NO. 21

—METHOD ONE—

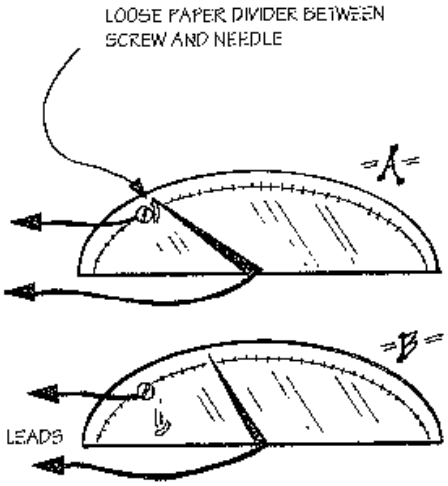
WORKING:

- CAR SPEEDS UP UNTIL SPEEDOMETER NEEDLE TOUCHES METAL SCREW
- BOMB CIRCUIT IS COMPLETED AND DEVICE EXPLODES



—METHOD TWO—

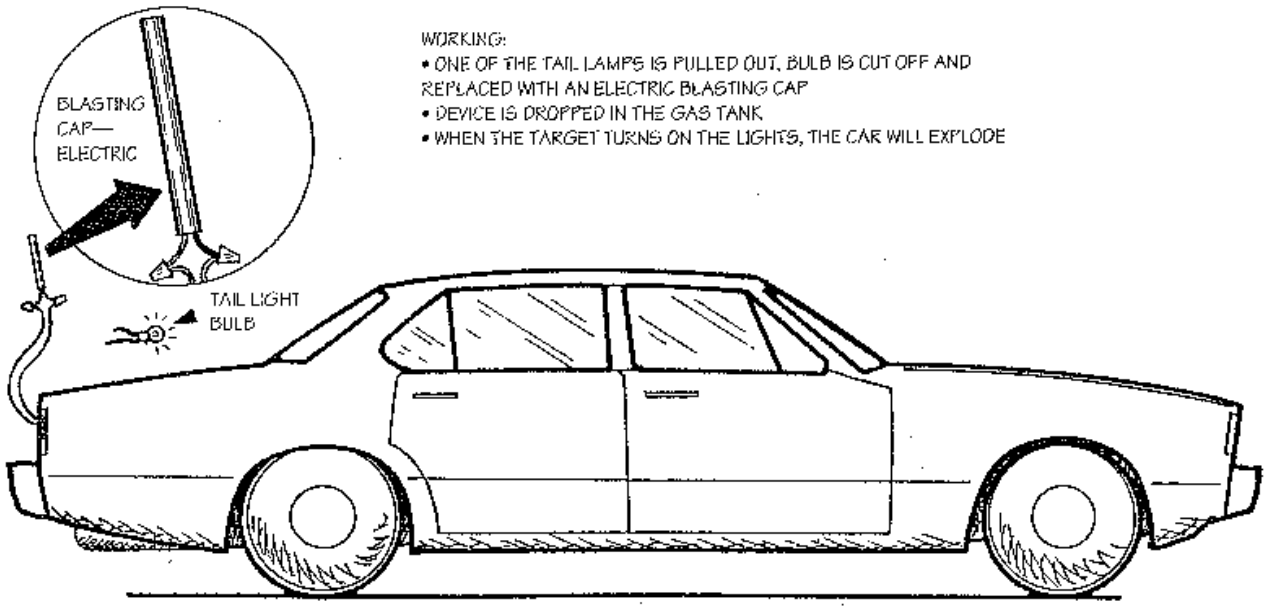
- CAR SPEEDS UP. SPEEDOMETER NEEDLE RISES; PAPER DIVIDER FALLS FREE
- VICTIM CANNOT SLOW DOWN OR NEEDLE WILL CONTACT SCREW, COMPLETE CIRCUIT, AND DETONATE BOMB



NOTE:
EITHER OF THESE METHODS CAN BE APPLIED TO ALMOST ANY METER OR GAUGE

SPEEDOMETER DEVICES

IMPROVISED CAR BOMB NO. 22

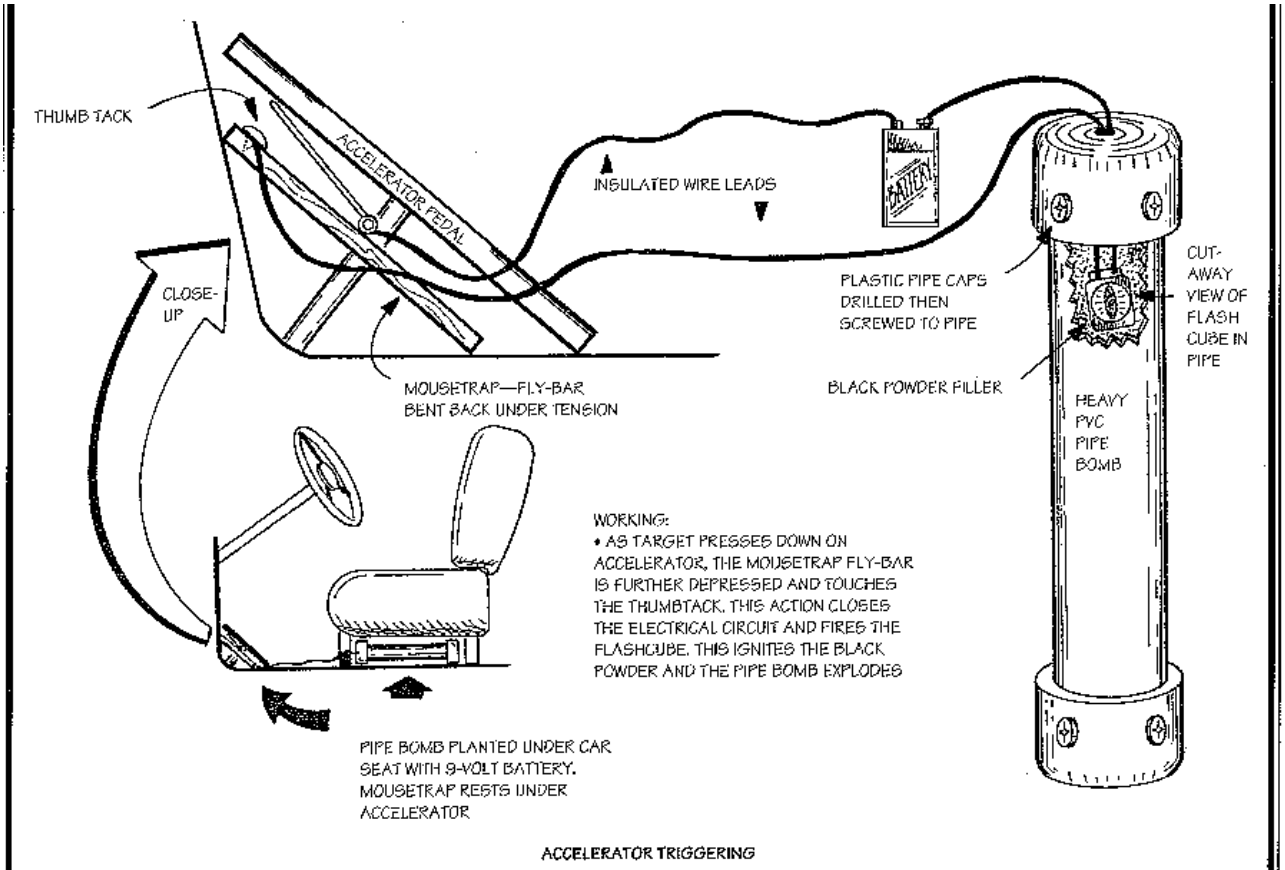


WORKING:
- ONE OF THE TAIL LAMPS IS PULLED OUT, BULB IS CUT OFF AND REPLACED WITH AN ELECTRIC BLASTING CAP
- DEVICE IS DROPPED IN THE GAS TANK
- WHEN THE TARGET TURNS ON THE LIGHTS, THE CAR WILL EXPLODE

OPTIONS:
- REAR TIRES DEFLATED AND REFILLED WITH FLAMMABLE ACETYLENE GAS
- GARBAGE BAGS FILLED WITH HIGH-TEST GASOLINE AND PLACED IN TRUNK

BLASTING CAP DEVICE

IMPROVISED CAR BOMB NO. 23

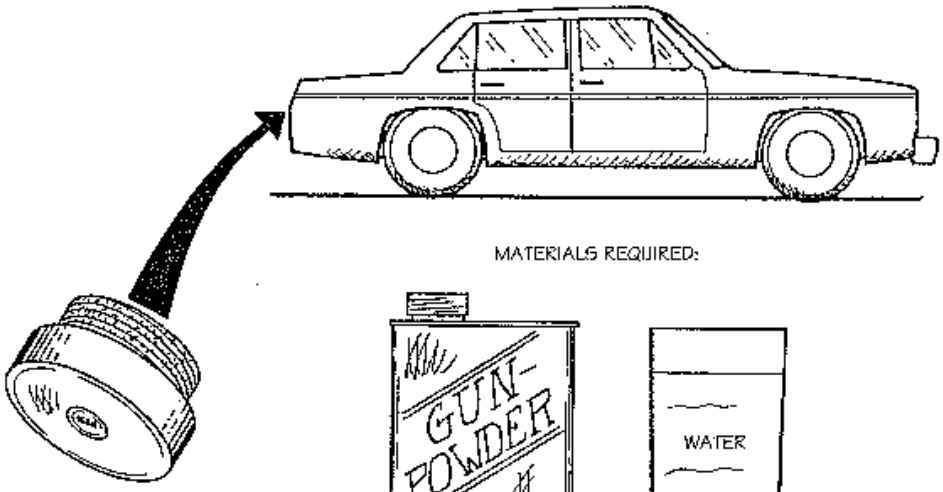

THUMB TACK
ACCELERATOR PEDAL
INSULATED WIRE LEADS
BATTERY
CLOSE-UP
PLASTIC PIPE CAPS DRILLED THEN SCREWED TO PIPE
CUT-AWAY VIEW OF FLASH CUBE IN PIPE
MOUSETRAP—FLY-BAR BENT BACK UNDER TENSION
BLACK POWDER FILLER
HEAVY PVC PIPE BOMB
WORKING:
• AS TARGET PRESSES DOWN ON ACCELERATOR, THE MOUSETRAP FLY-BAR IS FURTHER DEPRESSED AND TOUCHES THE THUMBTACK. THIS ACTION CLOSES THE ELECTRICAL CIRCUIT AND FIRES THE FLASHCUBE. THIS IGNITES THE BLACK POWDER AND THE PIPE BOMB EXPLODES
PIPE BOMB PLANTED UNDER CAR SEAT WITH 9-VOLT BATTERY. MOUSETRAP RESTS UNDER ACCELERATOR

ACCELERATOR TRIGGERING

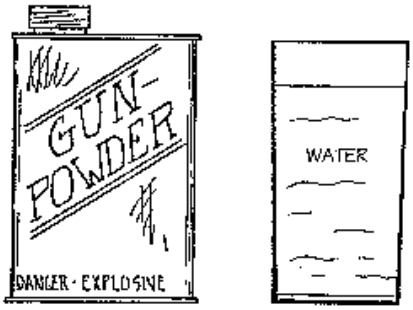
IMPROVISED CAR BOMB NO. 24

WORKING:

- GASOLINE CAP IS REMOVED.
- WATER AND **WET GUNPOWDER** IS PLACED ON THE THREADS OF THE GAS CAP
- GAS CAP IS IMMEDIATELY SCREWED BACK ON. THE POWDER MUST BE VERY WET!
- WHEN THE GUNPOWDER DRIES, THE BOMB IS SET
- WHEN THE VICTIM UNSCREWS THE GASOLINE CAP, THE METAL THREADS GRIND TOGETHER AND IGNITE THE GUNPOWDER. THIS IN TURN IGNITES THE GASOLINE VAPORS AND THE GAS TANK EXPLODES

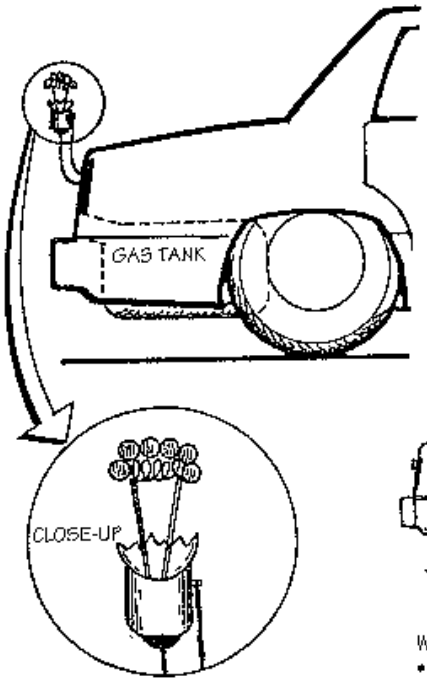


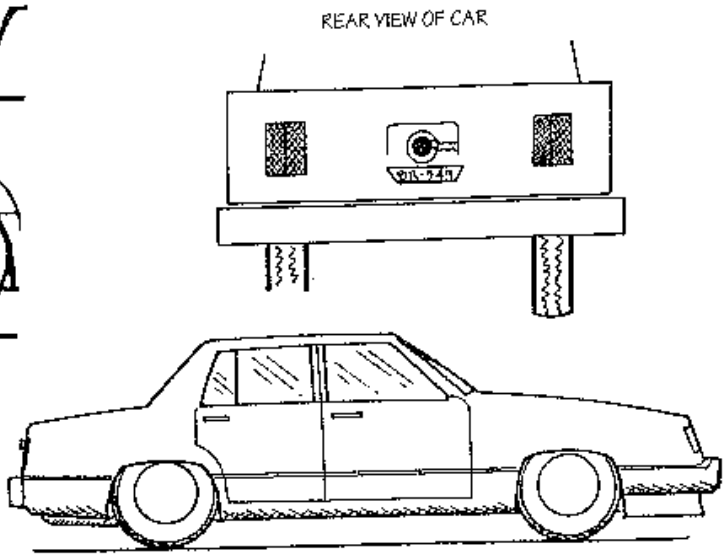
MATERIALS REQUIRED:



GIMMICKED GASOLINE CAP BOMB

IMPROVISED CAR BOMB NO. 25

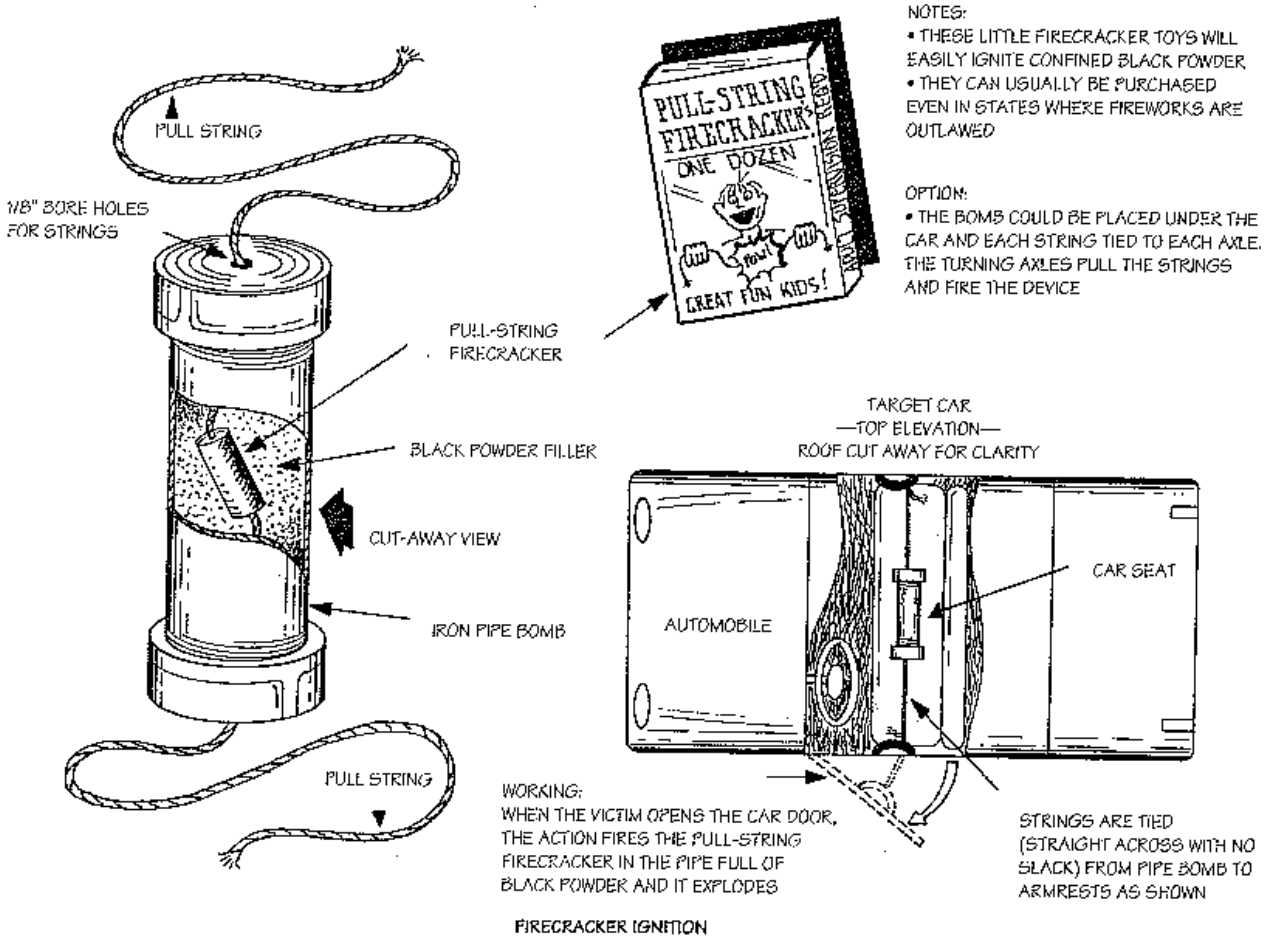




WORKING:
- REAR LICENSE PLATE LAMP IS REMOVED AND THE GLASS BULB CAREFULLY BROKEN SO THE FILAMENT REMAINS COMPLETELY INTACT
- MATCH HEADS ARE GLUED TO THE FILAMENT AND DROPPED IN THE GASOLINE TANK. THE INSULATED WIRE LEADS ALWAYS REMAIN CONNECTED TO THE BULB
- WHEN THE VICTIM TURNS ON HIS LIGHTS, THE BULB FIRES UP THE MATCH HEADS. THIS IGNITES THE GASOLINE VAPORS AND THE GASOLINE TANK EXPLODES

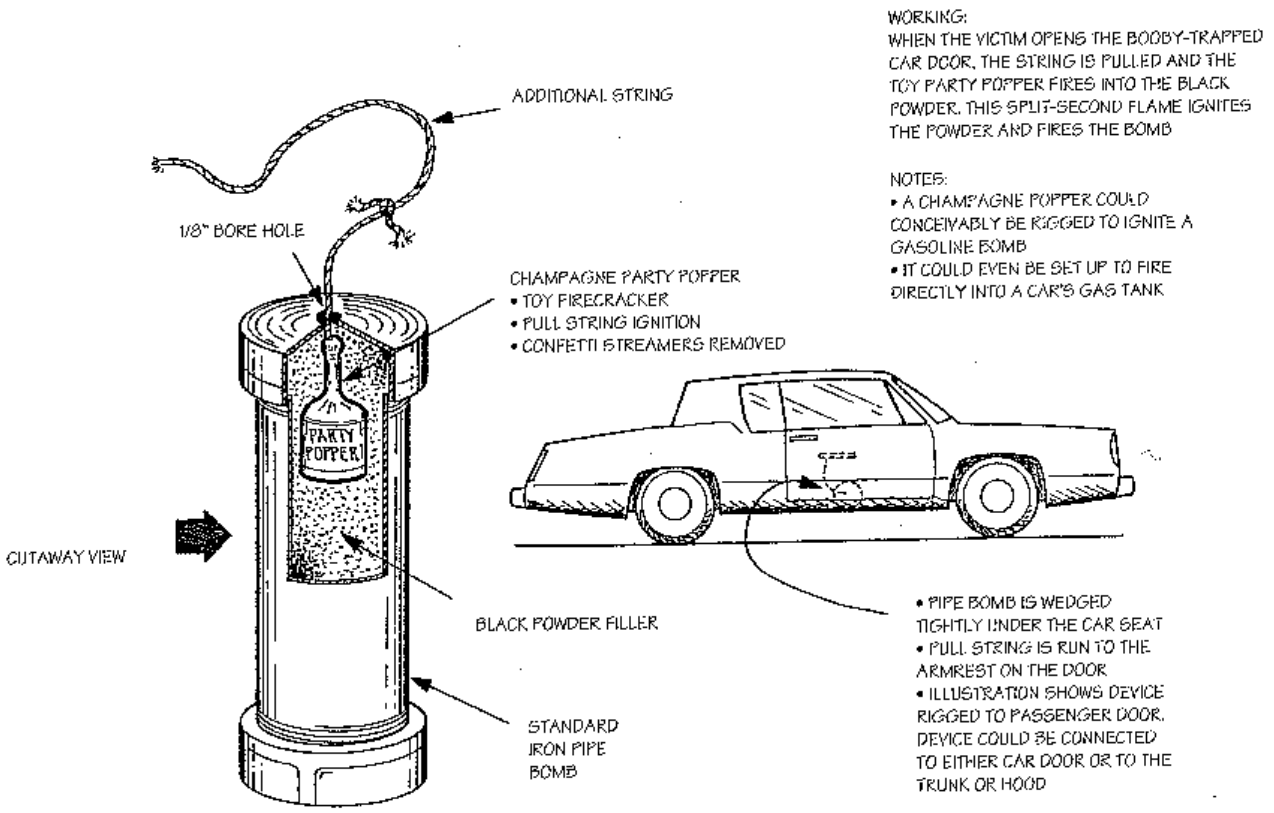
GASOLINE TANK BOMB

IMPROVISED CAR BOMB NO. 26


PULL STRING
1/8" BORE HOLES FOR STRINGS
PULL-STRING FIRECRACKER
BLACK POWDER FILLER
CUT-AWAY VIEW
IRON PIPE BOMB
PULL STRING
PULL-STRING FIRECRACKER
ONE DOZEN
GREAT FUN KIDS!
NOTES:
• THESE LITTLE FIRECRACKER TOYS WILL EASILY IGNITE CONFINED BLACK POWDER
• THEY CAN USUALLY BE PURCHASED EVEN IN STATES WHERE FIREWORKS ARE OUTLAWED
OPTION:
• THE BOMB COULD BE PLACED UNDER THE CAR AND EACH STRING TIED TO EACH AXLE. THE TURNING AXLES PULL THE STRINGS AND FIRE THE DEVICE
TARGET CAR
—TOP ELEVATION—
ROOF CUT AWAY FOR CLARITY
AUTOMOBILE
CAR SEAT
WORKING:
WHEN THE VICTIM OPENS THE CAR DOOR, THE ACTION FIRES THE PULL-STRING FIRECRACKER IN THE PIPE FULL OF BLACK POWDER AND IT EXPLODES
STRINGS ARE TIED (STRAIGHT ACROSS WITH NO SLACK) FROM PIPE BOMB TO ARMRESTS AS SHOWN

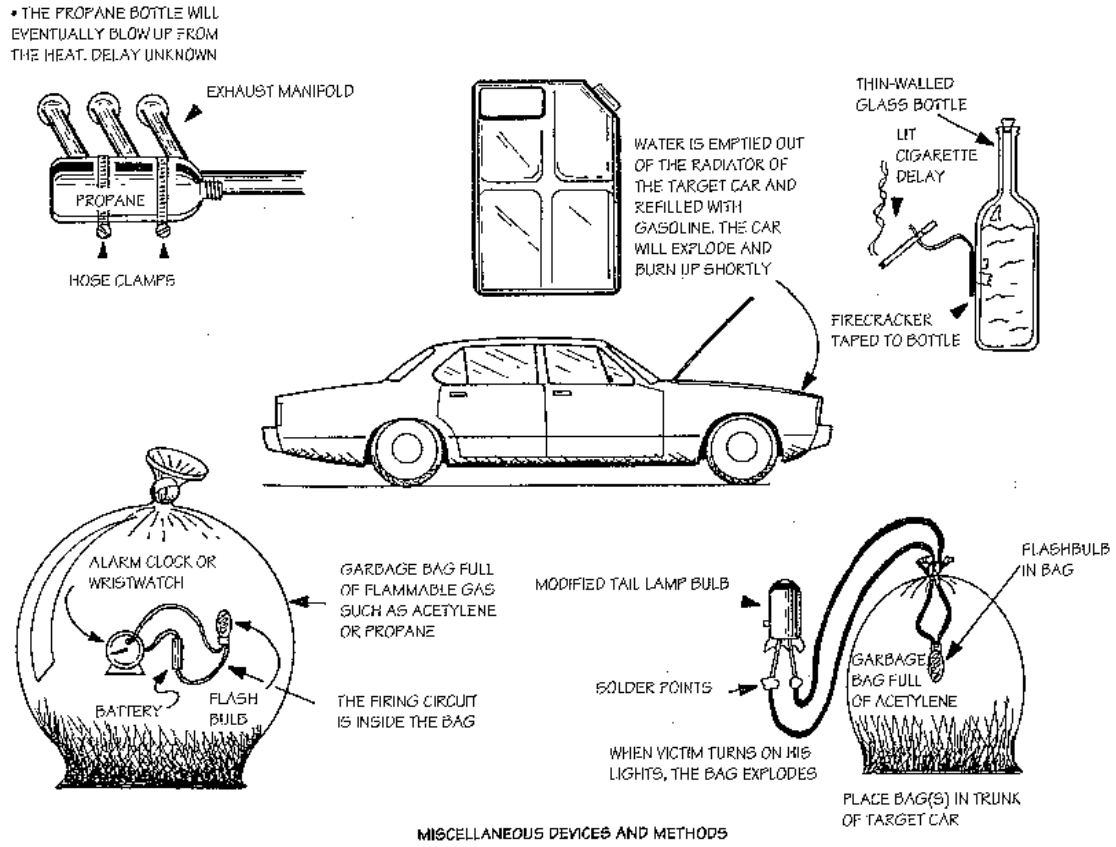
FIRECRACKER IGNITION

IMPROVISED CAR BOMB NO. 27


WORKING:
WHEN THE VICTIM OPENS THE BOOBY-TRAPPED CAR DOOR, THE STRING IS PULLED AND THE TOY PARTY POPPER FIRES INTO THE BLACK POWDER. THIS SPLIT-SECOND FLAME IGNITES THE POWDER AND FIRES THE BOMB
NOTES:
• A CHAMPAGNE POPPER COULD CONCEIVABLY BE RIGGED TO IGNITE A GASOLINE BOMB
• IT COULD EVEN BE SET UP TO FIRE DIRECTLY INTO A CAR'S GAS TANK
ADDITIONAL STRING
1/8" BORE HOLE
CHAMPAGNE PARTY POPPER
• TOY FIRECRACKER
• PULL STRING IGNITION
• CONFETTI STREAMERS REMOVED
PARTY POPPER
CUTAWAY VIEW
BLACK POWDER FILLER
STANDARD IRON PIPE BOMB
• PIPE BOMB IS WEDGED TIGHTLY UNDER THE CAR SEAT
• PULL STRING IS RUN TO THE ARMREST ON THE DOOR
• ILLUSTRATION SHOWS DEVICE RIGGED TO PASSENGER DOOR. DEVICE COULD BE CONNECTED TO EITHER CAR DOOR OR TO THE TRUNK OR HOOD

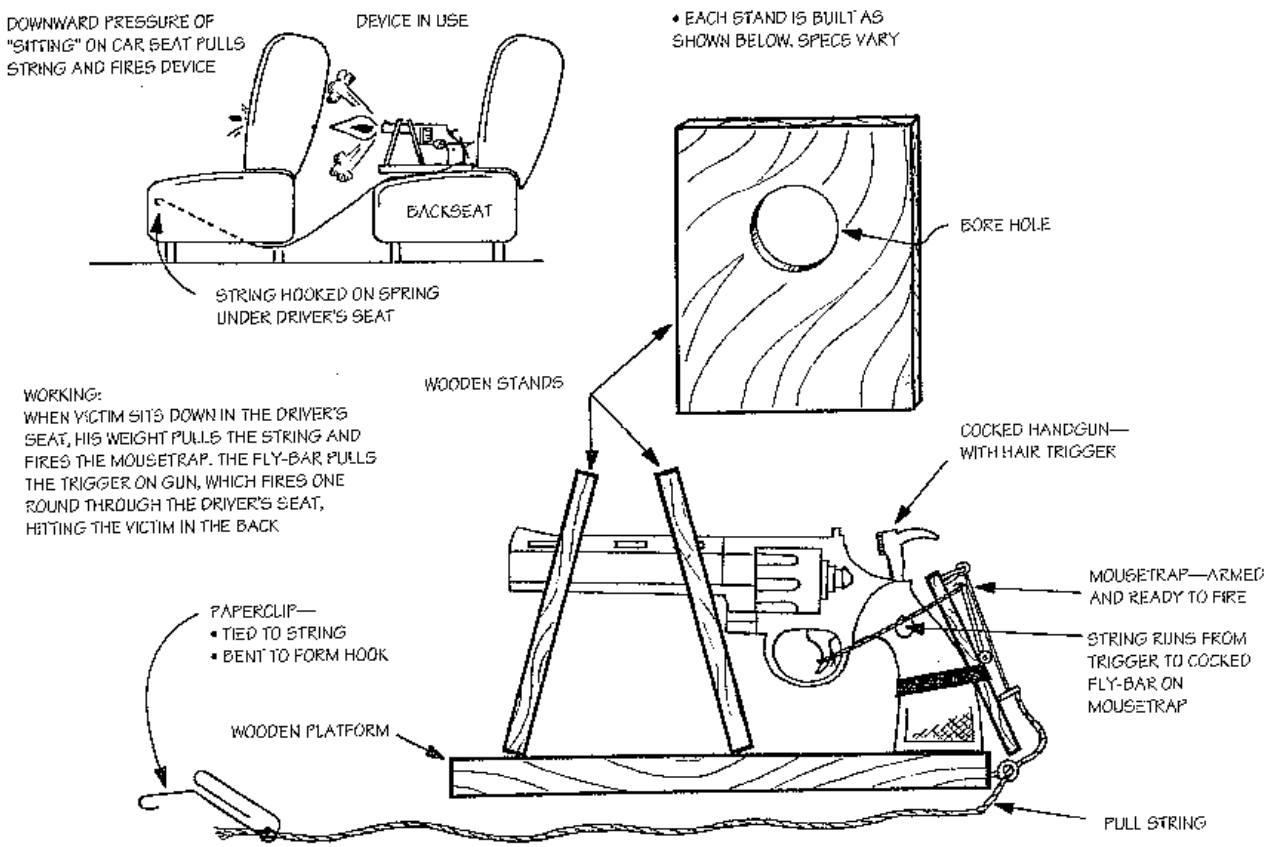
TOY PARTY POPPER IGNITION

IMPROVISED CAR BOMB NO. 28


• THE PROPANE BOTTLE WILL EVENTUALLY BLOW UP FROM THE HEAT. DELAY UNKNOWN
EXHAUST MANIFOLD
PROPANE
HOSE CLAMPS
WATER IS EMPTIED OUT OF THE RADIATOR OF THE TARGET CAR AND REFILLED WITH GASOLINE. THE CAR WILL EXPLODE AND BURN UP SHORTLY
THIN-WALLED GLASS BOTTLE
LIT CIGARETTE DELAY
FIRECRACKER TAPED TO BOTTLE
ALARM CLOCK OR WRISTWATCH
GARBAGE BAG FULL OF FLAMMABLE GAS SUCH AS ACETYLENE OR PROPANE
BATTERY
FLASH BULB
THE FIRING CIRCUIT IS INSIDE THE BAG
MODIFIED TAIL LAMP BULB
FLASHBULB IN BAG
SOLDER POINTS
GARBAGE BAG FULL OF ACETYLENE
WHEN VICTIM TURNS ON HIS LIGHTS, THE BAG EXPLODES
PLACE BAG(S) IN TRUNK OF TARGET CAR

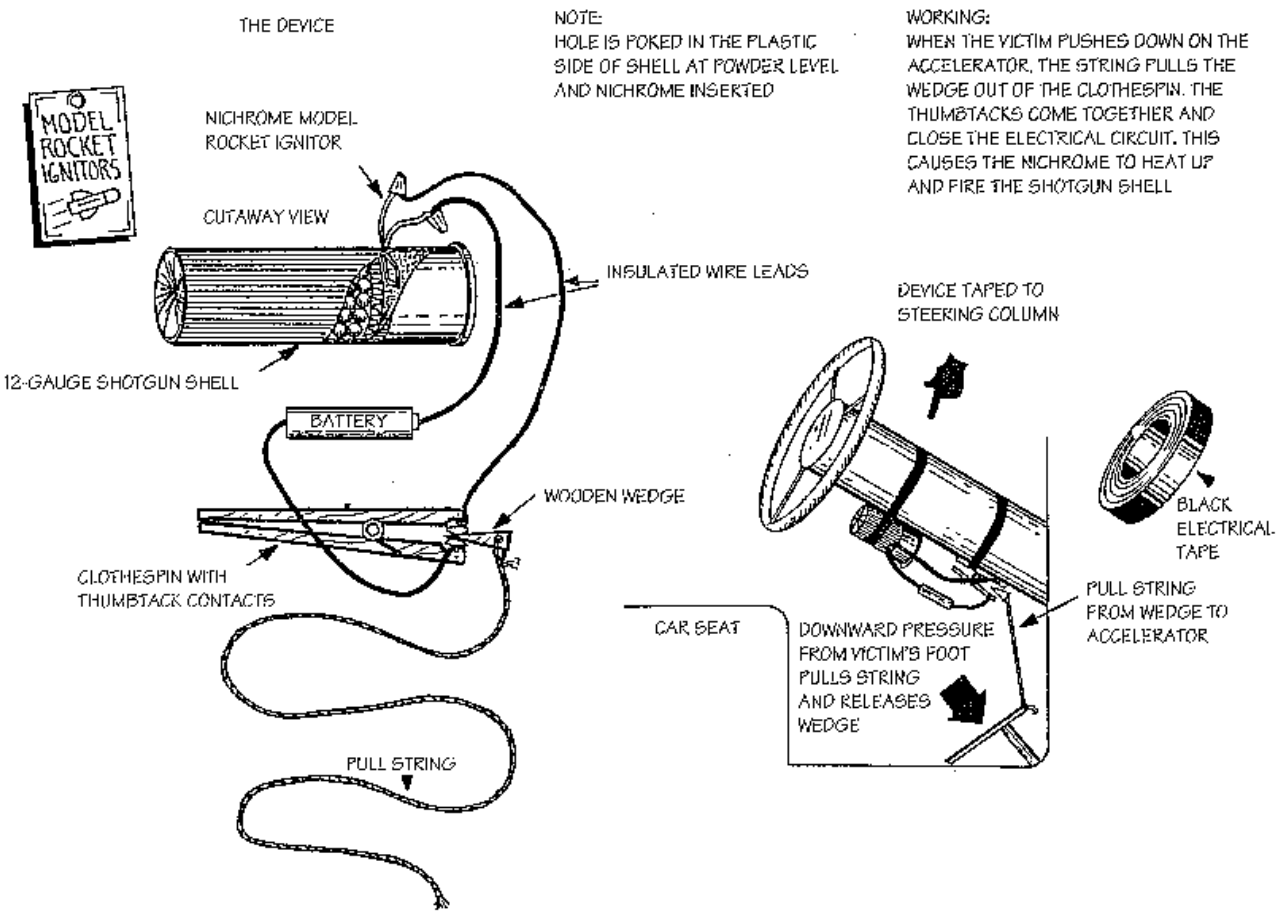
MISCELLANEOUS DEVICES AND METHODS

IMPROVISED CAR BOMB NO. 29


DOWNWARD PRESSURE OF "SITTING" ON CAR SEAT PULLS STRING AND FIRES DEVICE
DEVICE IN USE
BACKSEAT
STRING HOOKED ON SPRING UNDER DRIVER'S SEAT
• EACH STAND IS BUILT AS SHOWN BELOW. SPECS VARY
BORE HOLE
WOODEN STANDS
WORKING:
WHEN VICTIM SITS DOWN IN THE DRIVER'S SEAT, HIS WEIGHT PULLS THE STRING AND FIRES THE MOUSETRAP. THE FLY-BAR PULLS THE TRIGGER ON GUN, WHICH FIRES ONE ROUND THROUGH THE DRIVER'S SEAT, HITTING THE VICTIM IN THE BACK
COCKED HANDGUN— WITH HAIR TRIGGER
MOUSETRAP—ARMED AND READY TO FIRE
PAPERCLIP—
• TIED TO STRING
• BENT TO FORM HOOK
STRING RUNS FROM TRIGGER TO COCKED FLY-BAR ON MOUSETRAP
WOODEN PLATFORM
PULL STRING

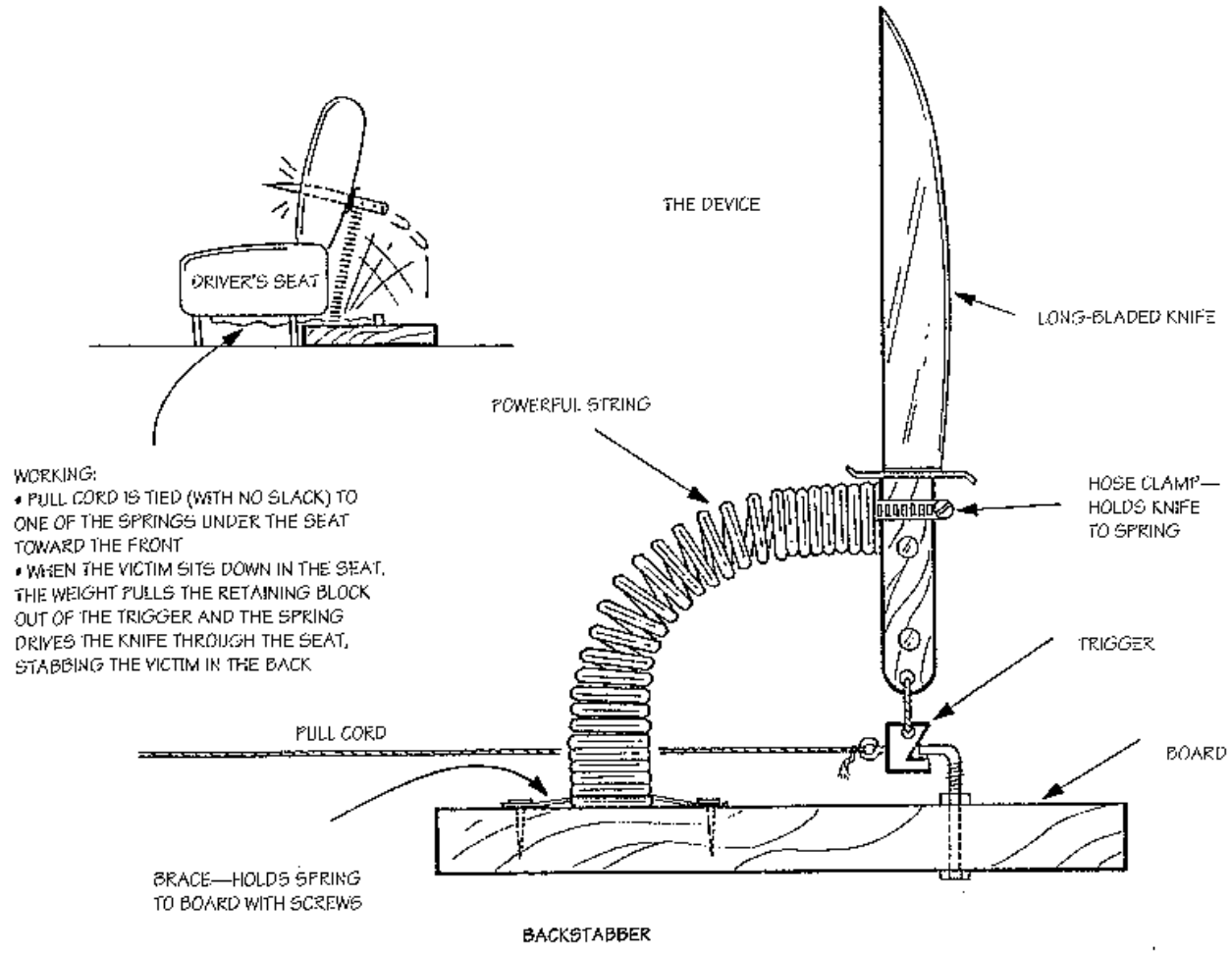
HANDGUN TRAP

IMPROVISED CAR BOMB NO. 30


THE DEVICE
NOTE:
HOLE IS POKED IN THE PLASTIC SIDE OF SHELL AT POWDER LEVEL AND NICHROME INSERTED
WORKING:
WHEN THE VICTIM PUSHES DOWN ON THE ACCELERATOR, THE STRING PULLS THE WEDGE OUT OF THE CLOTHESPIN. THE THUMBTACKS COME TOGETHER AND CLOSE THE ELECTRICAL CIRCUIT. THIS CAUSES THE NICHROME TO HEAT UP AND FIRE THE SHOTGUN SHELL
MODEL ROCKET IGNITORS
NICHROME MODEL ROCKET IGNITOR
CUTAWAY VIEW
INSULATED WIRE LEADS
12-GAUGE SHOTGUN SHELL
BATTERY
WOODEN WEDGE
CLOTHESPIN WITH THUMBTACK CONTACTS
PULL STRING
DEVICE TAPED TO STEERING COLUMN
BLACK ELECTRICAL TAPE
PULL STRING FROM WEDGE TO ACCELERATOR
CAR SEAT
DOWNWARD PRESSURE FROM VICTIM'S FOOT PULLS STRING AND RELEASES WEDGE

SHOTGUN SHELL BOOBY TRAP

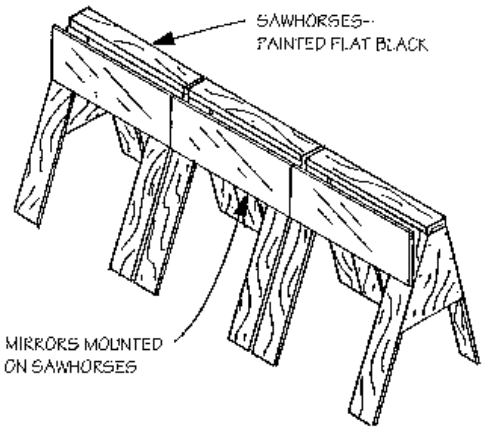
IMPROVISED CAR BOMB NO. 31


THE DEVICE
DRIVER'S SEAT
LONG-BLADED KNIFE
POWERFUL STRING
WORKING:
• PULL CORD IS TIED (WITH NO SLACK) TO ONE OF THE SPRINGS UNDER THE SEAT TOWARD THE FRONT
• WHEN THE VICTIM SITS DOWN IN THE SEAT, THE WEIGHT PULLS THE RETAINING BLOCK OUT OF THE TRIGGER AND THE SPRING DRIVES THE KNIFE THROUGH THE SEAT, STABBING THE VICTIM IN THE BACK
HOSE CLAMP—HOLDS KNIFE TO SPRING
TRIGGER
PULL CORD
BOARD
BRACE—HOLDS SPRING TO BOARD WITH SCREWS
BACKSTABBER

IMPROVISED CAR BOMB NO. 32

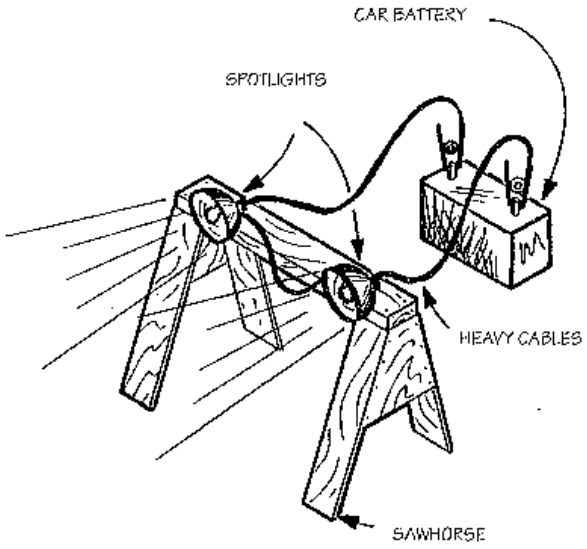
DEVICE IS PLACED IN THE ROAD
AROUND A SHARP CURVE SO IT
WON'T BE SEEN UNTIL IT'S TOO LATE

DRIVER SPEEDING ALONG ROAD BELIEVES HE IS ABOUT
TO BE IN A HEAD-ON COLLISION, SWERVES OFF ROAD



HIGHWAY MIRROR DECEPTION

WORKING:
AS WITH THE PREVIOUS DEVICE,
THIS ONE IS SET IN THE ROAD AT
NIGHT FACING THE ONCOMING
TARGET CAR. THE LIGHTS ARE SET
ON A TIMER OR REMOTE CONTROL.

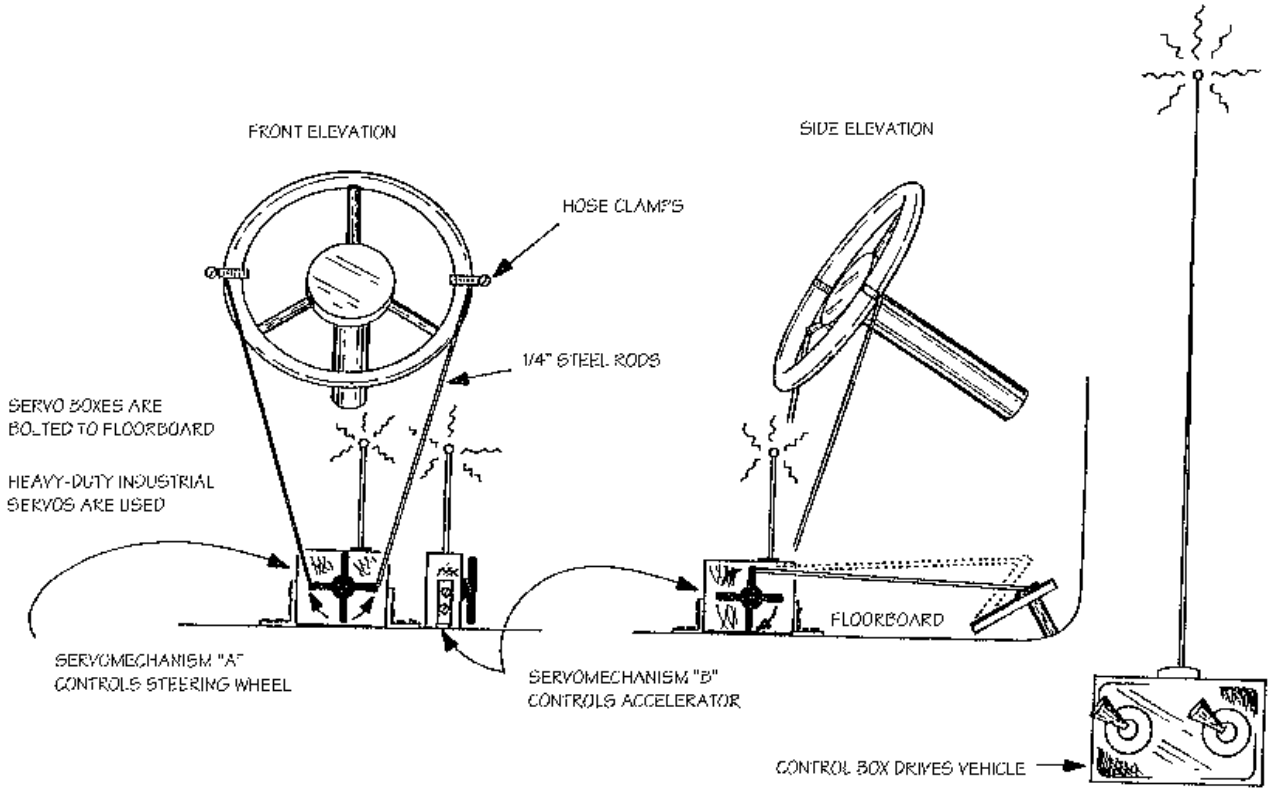


HIGHWAY SPOTLIGHT DECEPTION

IMPROVISED CAR BOMB NO. 33

USED TO DELIVER A CAR
LOAD OF EXPLOSIVES

VEHICLE IS CONTROLLED FROM A DISTANCE, SUCH
AS FROM A HIGH-RISE STRUCTURE, ROOFTOP, ETC.

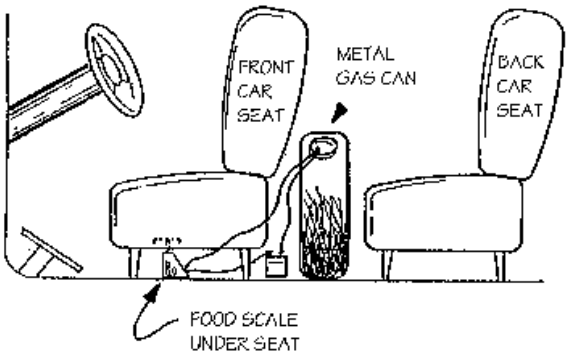


REMOTE CONTROL DRIVING SYSTEM

IMPROVISED CAR BOMB NO. 34

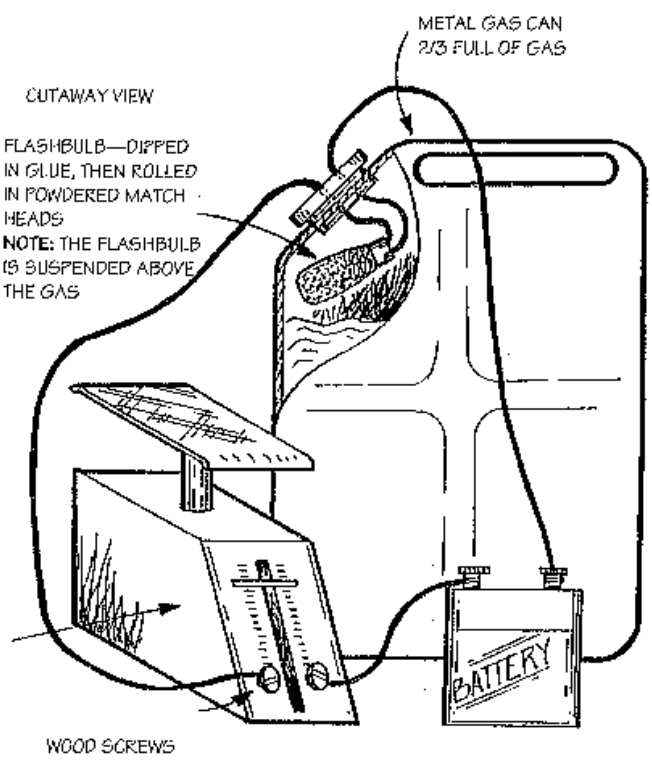
WORKING:
WHEN THE VICTIM SITS ON THE CAR SEAT, THE FOOD SCALE WEIGH PLATE IS DEPRESSED. THIS ACTION CAUSES THE METAL READ NEEDLE TO COMPLETE THE BRIDGE AND CLOSE THE ELECTRICAL CIRCUIT. THE FLASHBULB FIRES AND DETONATES THE GASOLINE

DEVICE IN PLACE



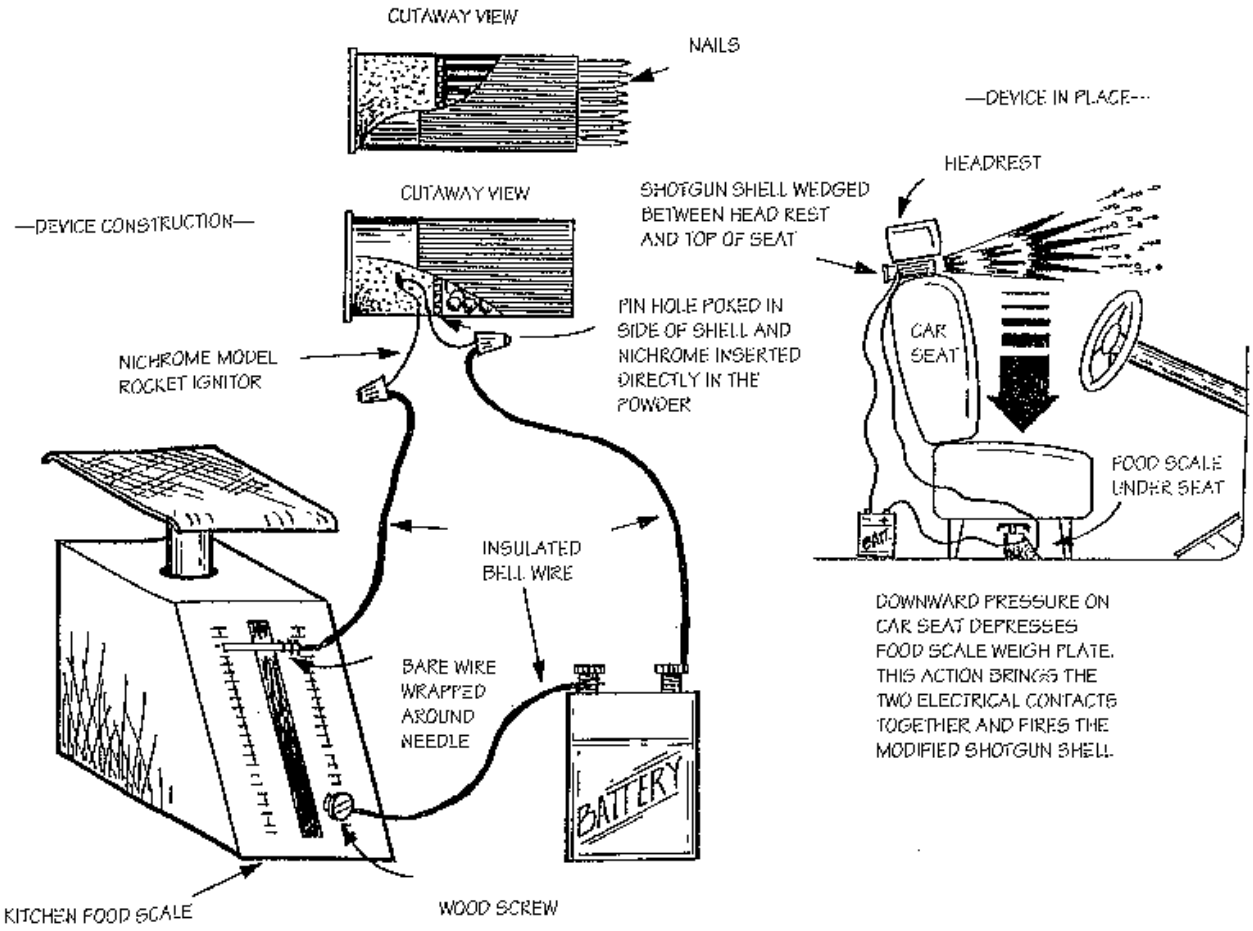
HOW THE DEVICE IS CONSTRUCTED

CUTAWAY VIEW


METAL GAS CAN 2/3 FULL OF GAS
FLASHBULB—DIPPED IN GLUE, THEN ROLLED IN POWDERED MATCH HEADS
NOTE: THE FLASHBULB IS SUSPENDED ABOVE THE GAS
PLASTIC FOOD SCALE WITH METAL NEEDLE
BATTERY
WOOD SCREWS

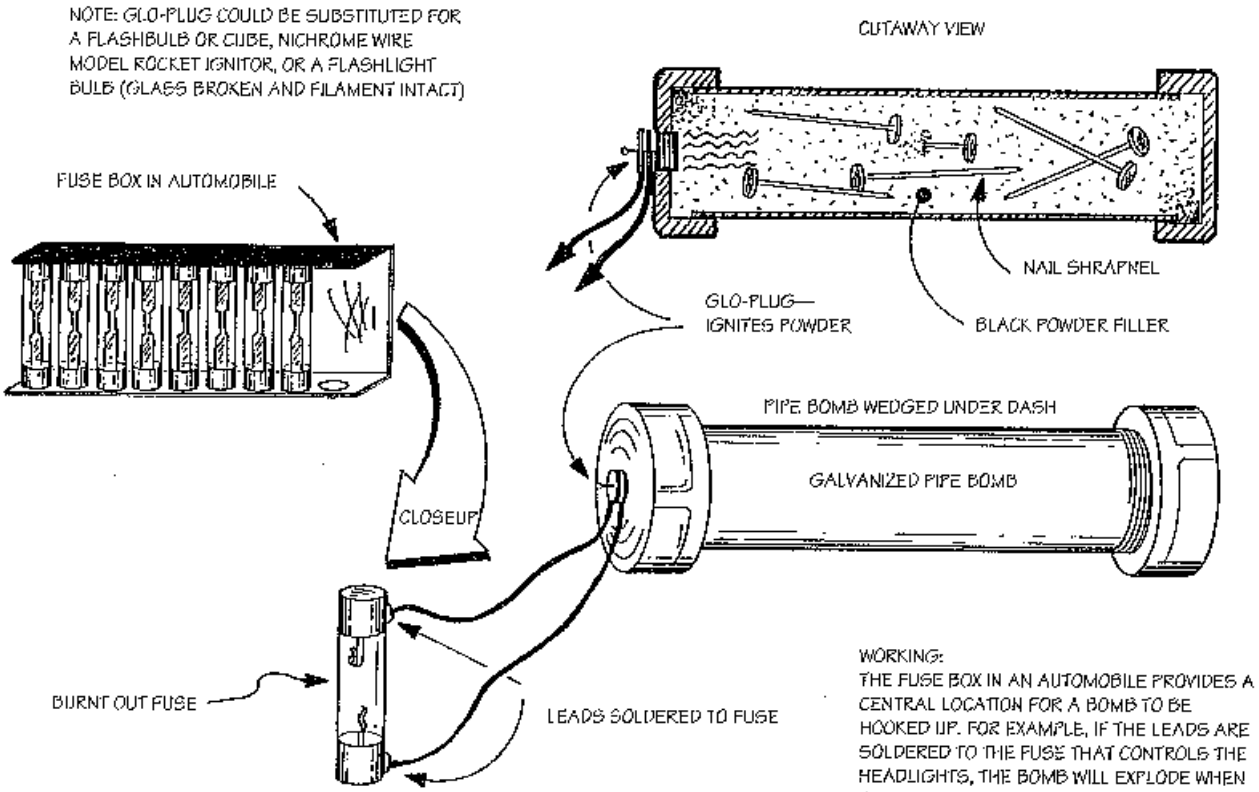
DEADLY AUTO INFERNO

IMPROVISED CAR BOMB NO. 35


CUTAWAY VIEW
NAILS
—DEVICE IN PLACE—
HEADREST
CUTAWAY VIEW
SHOTGUN SHELL WEDGED BETWEEN HEAD REST AND TOP OF SEAT
—DEVICE CONSTRUCTION—
PIN HOLE POKED IN SIDE OF SHELL AND NICHROME INSERTED DIRECTLY IN THE POWDER
NICHROME MODEL ROCKET IGNITOR
CAR SEAT
FOOD SCALE UNDER SEAT
INSULATED BELL WIRE
BARE WIRE WRAPPED AROUND NEEDLE
BATTERY
DOWNWARD PRESSURE ON CAR SEAT DEPRESSES FOOD SCALE WEIGH PLATE. THIS ACTION BRINGS THE TWO ELECTRICAL CONTACTS TOGETHER AND FIRES THE MODIFIED SHOTGUN SHELL.
KITCHEN FOOD SCALE
WOOD SCREW

DEADLY CAR SEAT DEVICE

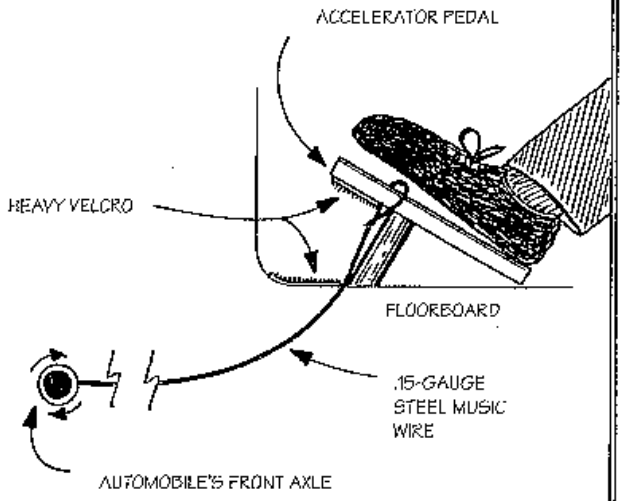
IMPROVISED CAR BOMB NO. 36


NOTE: GLO-PLUG COULD BE SUBSTITUTED FOR A FLASHBULB OR CUBE, NICHROME WIRE MODEL ROCKET IGNITOR, OR A FLASHLIGHT BULB (GLASS BROKEN AND FILAMENT INTACT)
CUTAWAY VIEW
FUSE BOX IN AUTOMOBILE
NAIL SHRAPNEL
GLO-PLUG— IGNITES POWDER
BLACK POWDER FILLER
PIPE BOMB WEDGED UNDER DASH
GALVANIZED PIPE BOMB
CLOSEUP
BURNT OUT FUSE
LEADS SOLDERED TO FUSE
WORKING:
THE FUSE BOX IN AN AUTOMOBILE PROVIDES A CENTRAL LOCATION FOR A BOMB TO BE HOOKED UP. FOR EXAMPLE, IF THE LEADS ARE SOLDERED TO THE FUSE THAT CONTROLS THE HEADLIGHTS, THE BOMB WILL EXPLODE WHEN THE HEADLIGHTS ARE TURNED ON

AUTO FUSE BOX DETONATION

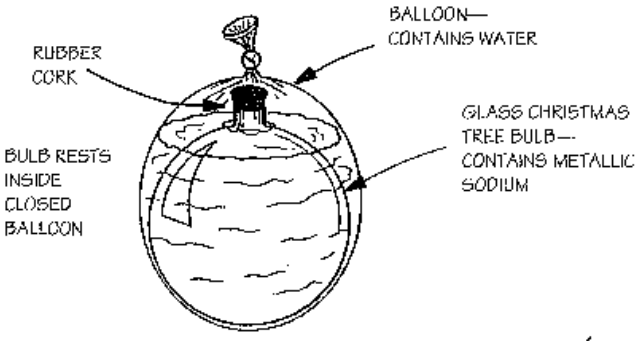
IMPROVISED CAR BOMB NO. 37

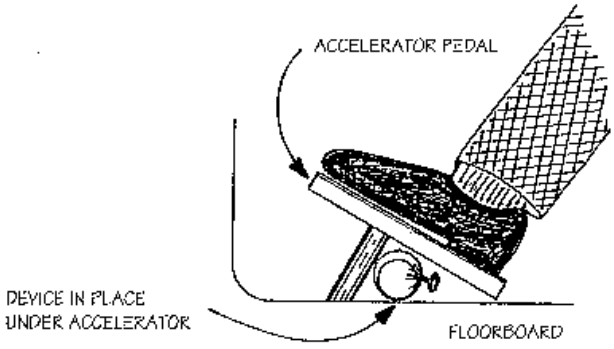
WORKING:
AS THE AUTOMOBILE MOVES IN EITHER DIRECTION, THE WIRE WINDS AROUND THE AXLE. THIS DRAWS THE ACCELERATOR TO THE FLOOR, WHERE THE VELCRO STRIPS MEET AND LOCK. NORMALLY, THE WIRE WILL SNAP AT THIS POINT. THE ACCELERATOR IS FLOORED AND THE CAR IS MOVING AT MAXIMUM SPEED, MOST LIKELY IN REVERSE



INFINITY ACCELERATOR

—THE DEVICE—

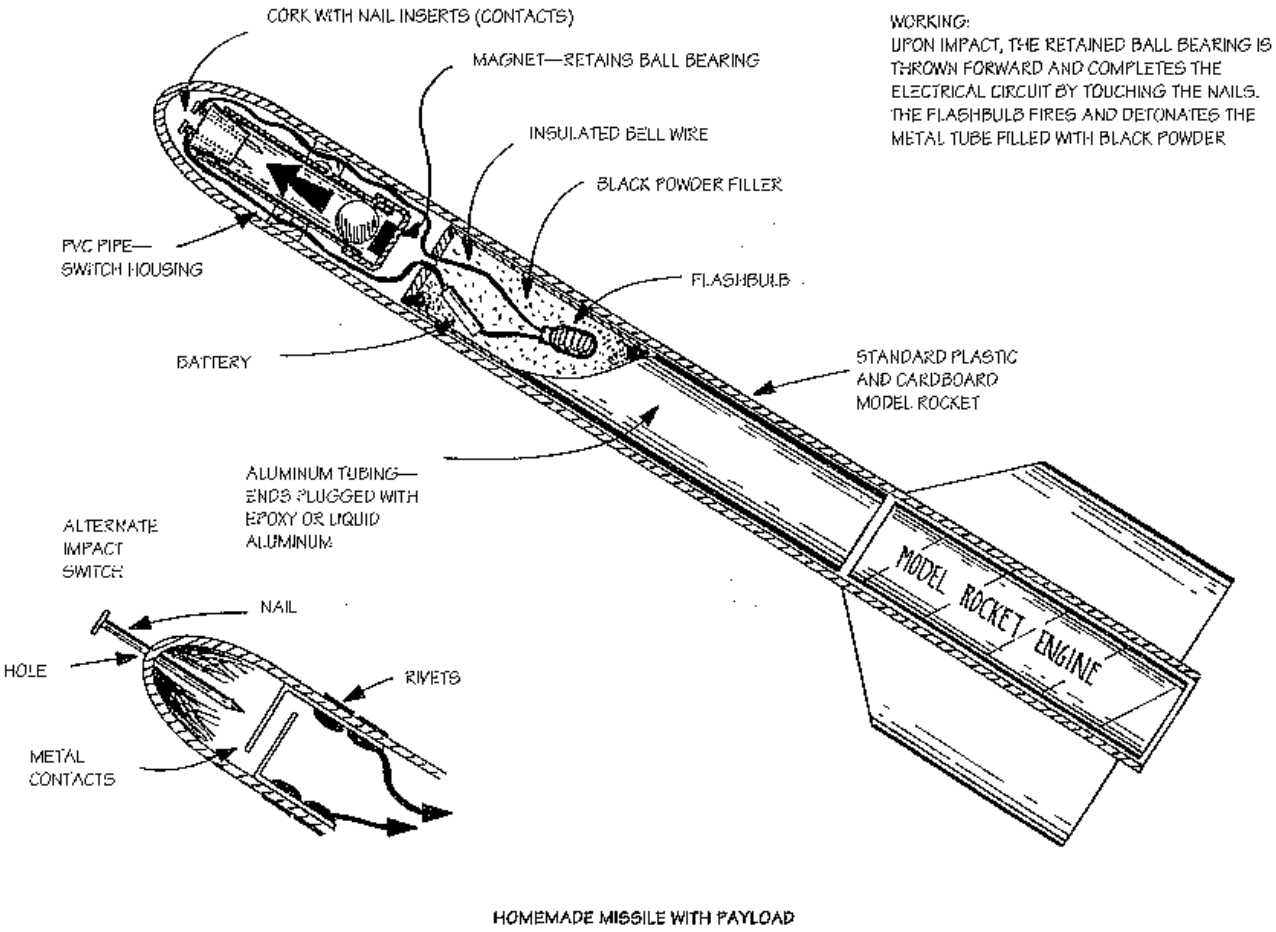

BALLOON— CONTAINS WATER
RUBBER CORK
GLASS CHRISTMAS TREE BULB— CONTAINS METALLIC SODIUM
BULB RESTS INSIDE CLOSED BALLOON



WORKING:
DOWNWARD ACCELERATION CRUSHES BULB IN BALLOON. THE CONTENTS MIX AND A FIRE AND EXPLOSION IS CREATED

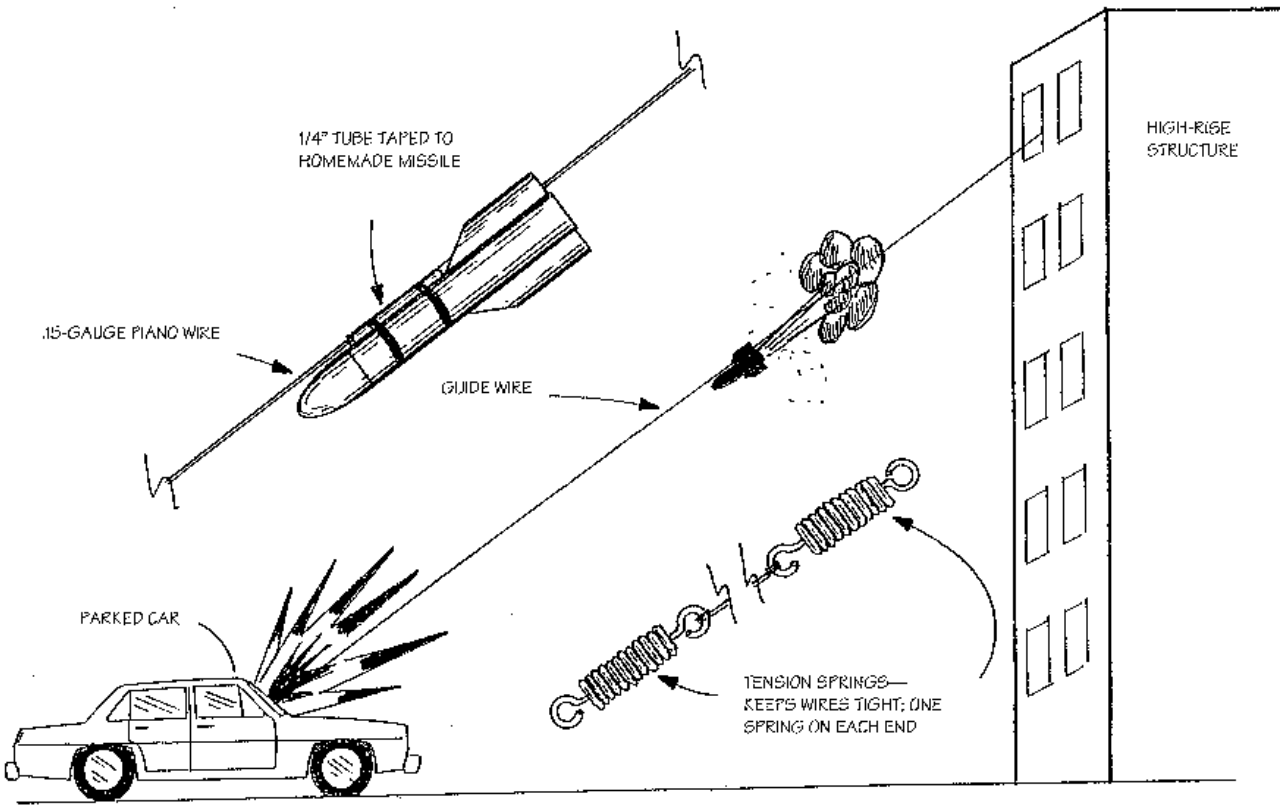
HYPERGOLIC FIRE STARTER

IMPROVISED CAR BOMB NO. 38



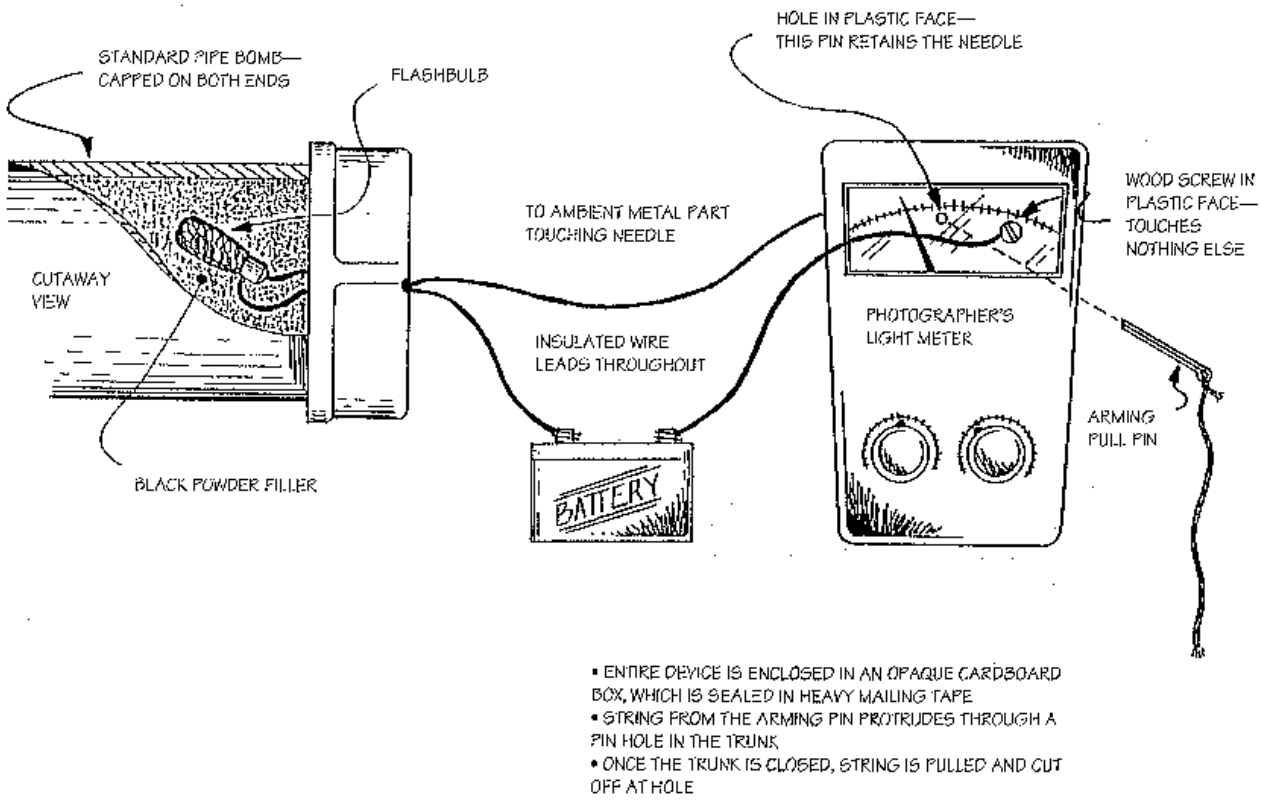
HOMEMADE MISSILE WITH PAYLOAD

IMPROVISED CAR BOMB NO. 39



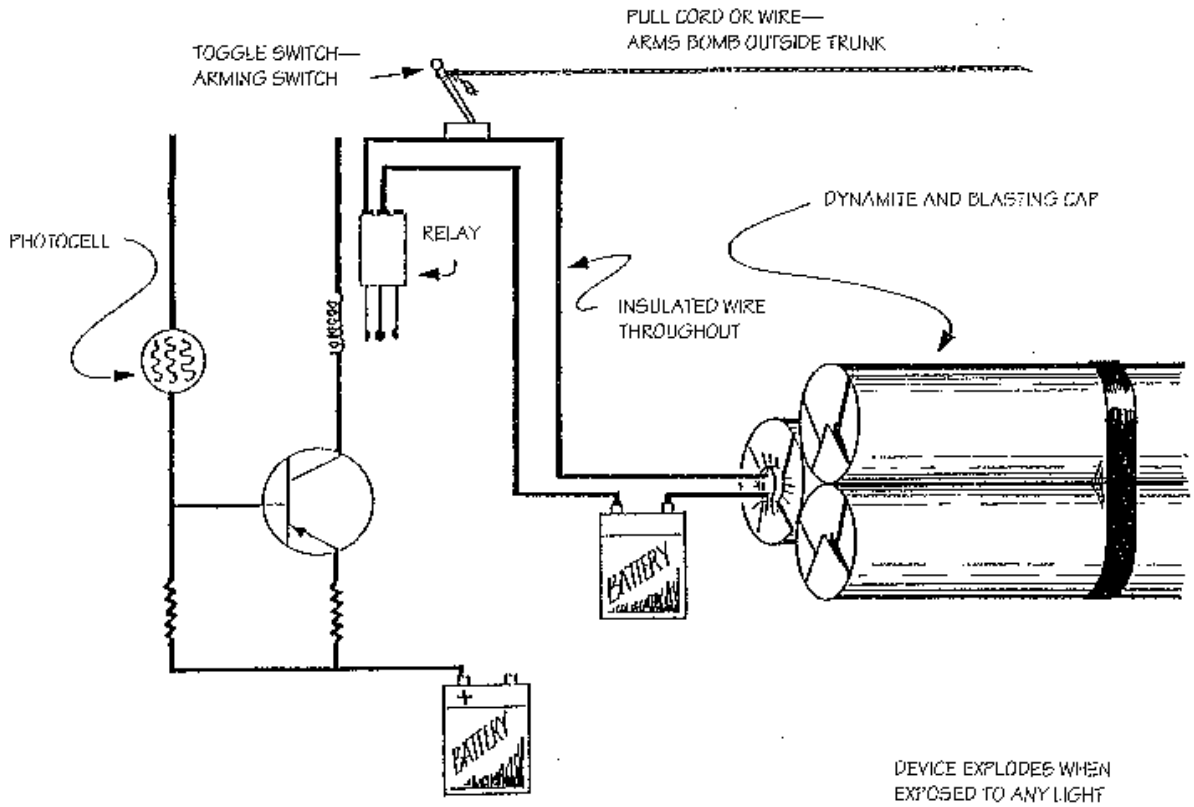
HOMEMADE MISSILE IN USE

IMPROVISED CAR BOMB NO. 39 (CONT.)



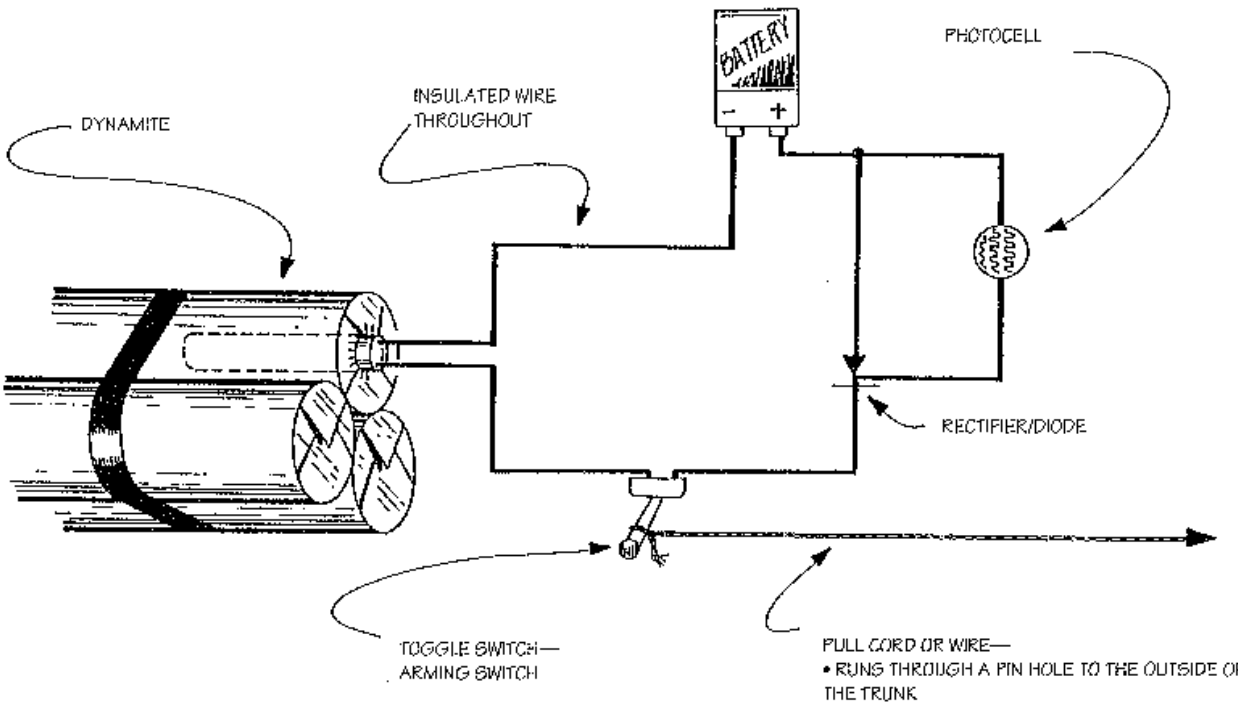
LIGHT-SENSITIVE TRUNK BOMB 1

IMPROVISED CAR BOMB NO. 40



LIGHT-SENSITIVE TRUNK BOMB 2

IMPROVISED CAR BOMB NO. 41


DYNAMITE
INSULATED WIRE THROUGHOUT
BATTERY
PHOTOCELL
RECTIFIER/DIODE
TOGGLE SWITCH—ARMING SWITCH
PULL CORD OR WIRE—
• RUNS THROUGH A PIN HOLE TO THE OUTSIDE OF THE TRUNK
• ONCE THE DEVICE IS SEALED IN TOTAL DARKNESS, THE CORD IS PULLED TO ARM THE DEVICE
• CORD IS CUT OFF DIRECTLY OUTSIDE THE PIN HOLE
BLASTING CAP AND DYNAMITE COULD BE REPLACED BY A PIPE BOMB

LIGHT-SENSITIVE TRUNK BOMB 3

IMPROVISED CAR BOMB NO. 42

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Introduction

This field manual is designed to provide Special Forces (SF) engineers and unconventional warfare (UCW) personnel with several expedient methods of remote control (RC) detonation of explosive devices in a tactical unconventional warfare environment. The use of radio transmitters and receivers in the application of demolitions is, by its very nature, an exacting and precise science. It is assumed that the reader has no background in electronics or communications. However, the techniques described in this manual should only be applied by a skilled demolitions or engineering specialist with knowledge of the safe handling and deployment of munitions in a tactical environment.

The basic premise of this field manual is to meet the needs of the UCW commander and his engineering personnel in the construction and deployment of short- and medium-range RC detonation equipment without the use of special tools or sophisticated electronics skills.

The devices described in this manual can be designed and constructed using typically available materials in the urban UCW theatre in a minimal amount of time. *Commanders are*

advised to use caution and discretion in making this manual and all related documents available to indigenous personnel.

Chapter 1

Concept and Tactical Application of RC Detonation

The use of radio equipment to detonate any type of explosive device is limited by several factors. The type of transmitter and receiver available, distance from the target where detonation will occur, actual weather conditions, and possibility of "jamming" (radio frequency interference from both friendly and enemy communications equipment in the area) are all critical aspects of successful detonation. Although it is important to be aware of these considerations, testing and careful modification of the devices explained in this manual will eliminate problems with most of the above factors if the procedures are followed correctly. To verify your work, a final "dry run" field-test of your equipment should be done prior to positioning and arming the device.

It should be noted at this point that a "hard wire" emplacement of demolitions is considered to be more reliable and less sensitive to unknown conditions than RC detonation and should be implemented whenever it is technically feasible.

The use of RC detonation techniques is limited to the imagination of the UCW commander and his engineering and demolitions personnel. The following techniques constitute only a small portion of those available to anyone who wants to

use creativity and improvisation to their tactical advantage. It is technically possible to detonate an explosive device from any location on the planet using radio communications equipment that is commercially available or easily built by a skilled, electronics-trained demolitions specialist.

DESCRIPTION OF A TYPICAL RC SYSTEM

There are several basic components to an RC system that are common to all such devices. Figure 1 illustrates each of these components. An RC device is composed of a *transmitter* and *receiver* that are tuned to the same radio frequency (RF). The radio transmitter sends a signal over the airwaves, which is detected by the receiver. The RF contains not just a signal but also an audio tone *or* a group of tones modulated by the transmitter and demodulated by the receiver. These tones are known as *electronic pulses* and the signal used by an RC device is known as *pulse-coded modulation* (PCM).

The receiver is always on, waiting for the signal to be sent from the transmitter. When the detonation switch is depressed by the transmitter operator, the receiver detects the transmission, demodulates the PCM from the RF signal, and switches the circuit, which sends current to the blasting cap and causes it to explode and detonate the munitions. This is a rather simplistic explanation of what actually occurs during RC detonation, but it is a suitable explanation that is easy to understand and apply.

The RC devices that can be constructed in the field will all use basic electronic components, which will then be modified by either the demolitions or communications team member for use

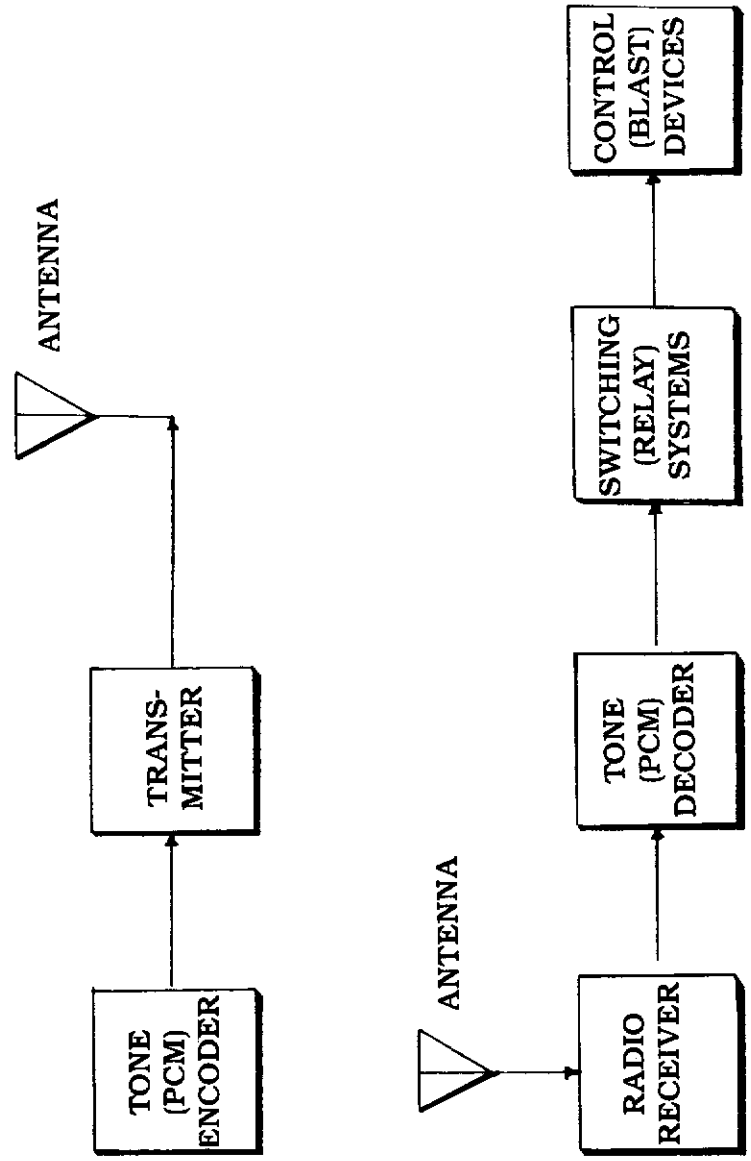


Figure 1

as a radio detonation device.

There are many common consumer electronics devices available throughout the world suitable for modification as RC devices. Although not specifically designed for the purpose of remote detonation of explosives, these items can be easily modified and used for this purpose, often with little or no change in the actual circuit involved.

The following consumer electronic devices are all capable of either short- or long-range RC detonation:

- Cordless electronic touch-tone phone
- Citizens band radio transceiver
- AM-FM portable "Walkman" type receiver
- FM wireless microphone
- Automobile "silent" paging alarm system
- Wireless intercom system
- Children's toy walkie-talkies
- Radio paging system
- Cellular mobile telephone
- VHF police scanner

Each of the above devices is either a radio receiver, transmitter, or both. The selection and modification of any particular device should be based on availability and specific application needs. Some of these devices are more limited in their range than others, and some are more sensitive to radio frequency interference (RFI). If it is possible to obtain any of these devices at random, then determine your specific needs and refer to Figure 2 for the most ideal device for your application.

Field personnel should not overlook their issued radio communications equipment for RC applications. Most portable radio transceivers

are very suitable for RC use. Obviously, a careful site survey and emplacement of team communications equipment well out of the blast zone should be implemented prior to detonation.

The following chapters will outline the expedient and reliable modification of each of the above consumer electronic items for use as an RC detonation device. For training purposes and universal availability of components, this manual will suggest using parts and tools available at any Radio Shack outlet in the United States.

Figure 2. Applications Table

DEVICE	RANGE	MOD-TIME	RELIABILITY
A	1 mile	2 hours	FAIR
B	5 miles	.5 hour	GOOD
C, D	1 mile	1 hour	FAIR
E	8 miles	1 hour	VERY GOOD
F	1/4 mile	1 hour	FAIR
G	1/4 mile	1 hour	FAIR
H	NA	10 minutes	EXCELLENT
I	35 miles	1 hour	EXCELLENT

DEVICE

A—cordless phone
B—CB radio
C—Walkman radio
D—wireless mike
E—auto page
F—wireless intercom
G—toy walkie-talkie
H—radio paging system
I—cellular mobile phone or VHF scanner

RANGE — Maximum range for PCM transmission

MOD-TIME — Time required to modify commercial unit

RELIABILITY — Comparing incidence of failure, interference, etc.

Chapter 2

Basic Electronics Theory and Equipment

In order to modify the devices described in this field manual, it is necessary to know how to use several electronic tools and pieces of equipment. This section is not meant as a replacement for more intensive electronics training but rather as a basic "primer" in elementary electronics. The following tools and test equipment will be needed to modify most of the devices outlined:

- Screwdriver (medium), flat tip
- Screwdriver (small), flat tip
- Screwdriver (medium), Phillips head
- Needle-nose pliers
- Wire cutters (small)
- Soldering iron (pencil type), 30 watt
- Volt-ohmmeter (VOM)
- Hook-up wire, solder, etc.

The Volt-ohmmeter required should be able to test AC voltage, DC voltage, resistance (ohms), and current (amps), as well as be battery-operated for field use. Radio Shack's model #22-212 pocket multitester is inexpensive and very suitable for this application.

The soldering iron should be of sufficient wattage to desolder heavy lug-type connections on

power supplies, as well as make strong connections to high-current electrical cables. Radio Shack model #64-2067 is recommended. If your intended area of operations does not have AC power capabilities, then it is recommended that you obtain a multipurpose, self-contained pocket gas torch for use as a field soldering iron, such as Radio Shack model #64-2164.

UNDERSTANDING BASIC ELECTRICITY

Electricity is measured in *volts*. Voltage is the value of electric current in relation to its intensity. The higher the voltage, the more force the electric current has. Electricity is also measured in *amps* (amperes). Amperage is the density or strength of the electric current.

If you compare a wire carrying electricity to a hose carrying water, the speed of the water (the water pressure) would be the voltage and the amount of water (or the water density) would be the amps.

Wattage is the voltage multiplied by the amperage of a device. For example, a light bulb that uses 100 volts and 1 amp of current is called a 100-watt bulb.

Resistance is the ability of an electrical conductor to allow current to pass through its mass. Resistance is measured in *ohms*.

Electrical energy is generally of two different types: *alternating current* (AC) or *direct current* (DC). Alternating current is voltage that changes or alternates in intensity. AC voltage is what comes out of the wall in your home, usually at a force around 110 volts. You can measure this voltage with your VOM by placing the setting on AC Volts and putting the probes directly into the wall socket.

Direct current is voltage that stays constant. All batteries are direct current. You can check your flashlight D cells with your VOM by setting the unit on DC Volts and placing the probes on each end of the battery. Note that if you connect them incorrectly, the meter needle slams to the left. This is because DC voltage has a positive and a negative side to it. Your flashlight battery should read 1½ volts. If it reads lower than 1 volt, then the battery is probably too weak to be used in your flashlight.

The VOM can also be used to test resistance. Set the VOM on Ohms and put the two probes together. The meter should read 0, because there is no resistance between the two probes. The VOM can therefore be used to check continuity; when running your detonation wire to a blasting cap, you can check the entire length for open or damaged wire by connecting the pair of wires together on one end and then checking the other end with your VOM. If it reads 0, then it is a good pair of wires. Use the VOM to test resistance in fuses and other electronic detonation components.

Caution: Do not attempt to check the resistance of a cap or any other type of electrical *ignition* device. The small amount of voltage that runs the ohmmeter section of your VOM will easily ignite the blasting cap.

MODIFICATION OF THE POWER SUPPLY

The main modification you will be performing on the devices described in this manual will be on the *power supply* section of the device. The power supply converts the AC wall voltage into DC for the circuitry inside the device, which needs a stable constant voltage.

The power supply is very easy to recognize in any electronic device. Always unplug the unit before working on it. Disconnect the power and then take the device out of its case by unscrewing the bottom set of screws. Follow the AC plug to the circuit board and it will lead to a large metal device called a *transformer*. The transformer is used to step down the AC from 110 volts to either 24, 12, 9, or 6 volts AC.

Plug the unit in again and use your VOM to see what the voltage is on the other end of the transformer. The transformer is usually the biggest component on the circuit board. Unplug the unit again and follow the circuit to the *diodes* or *bridge rectifier circuits* (see Figure 3). After the rectifier circuits, you will find a large- to medium-sized cylinder called an *electrolytic capacitor*. The capacitor takes the rectified AC and evens it out into a stable form of DC. This is where you want to set your VOM on DC Volts and measure the voltage coming out to find out how much DC the device you are modifying requires to run.

Plug the device back in and check the voltage at the two lugs underneath the capacitor. That voltage will usually be between 3 and 12 volts DC. This is where you are going to modify the unit to run on batteries. Unplug the device and plug in your soldering iron.

Soldering is very easy as long as you keep the iron clean and avoid using too much solder. As soon as the iron is hot (it takes about three to five minutes to heat up), you should "tin" the tip of your iron with some solder and then wipe the tip of the iron off with a damp cloth. Do this regularly to keep the iron clean and to avoid replacing the tip.

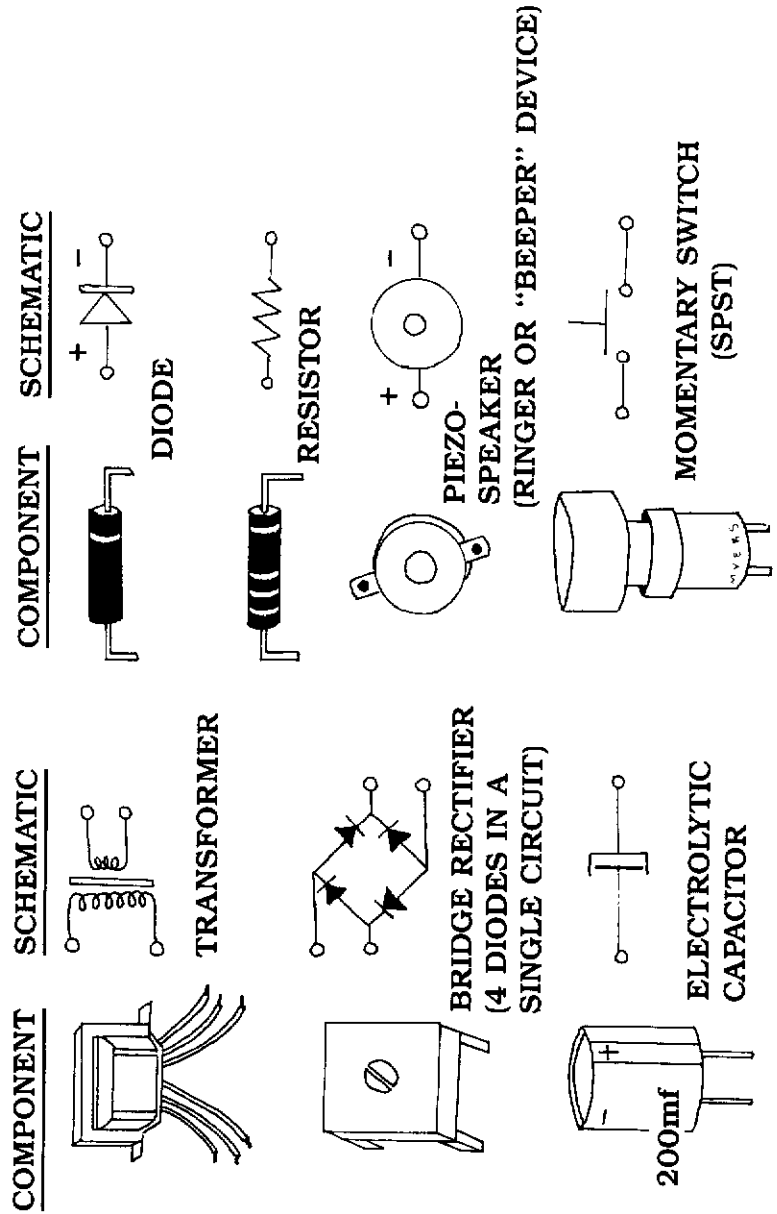


Figure 3

Use the iron to heat up the soldered terminals under the capacitor. When the solder melts, lift up each end of the capacitor and pull it carefully out of the socket on the circuit board.

Next take two long pieces of hook-up wire and strip the ends. It's best to use two different colors of wire, such as black and red. Place the red wire into the hole on the circuit board that was the positive (+) side of the capacitor (the capacitor is marked with a positive and negative side), then use your iron and a *small* amount of solder to set the wire in place. Connect the black wire to the negative (–) side of the capacitor socket.

You have just modified a device that plugs into the wall to run on batteries in the field. Whatever voltage you found at the capacitor terminals is the correct voltage at which to operate the device.

Chapter 3

Field-Expedient Audio Modulated Relay

There is an occasional need for a quick solution to a radio detonation problem. The UCW commander may need a field-expedient device for one-time use in an ambush or an assassination. The device must be completely destroyed in the blast and should therefore be as simple in design as possible. Once in the field, the availability of test equipment, tools, or components for an RC system may be very limited.

It is therefore useful to have the skill to create a *field-expedient audio relay* (FEAR) system from virtually any available materials. The FEAR unit is designed to operate off the audio signal from any available receiver and to detonate the munitions when an audio signal of sufficient duration is received from the transmission source. The FEAR unit does not require a separate power source to function because it utilizes the receiver's audio output to function, nor does it require semiconductors or electronic components. The design is flexible and materials are generally available in any UCW area of operations (AO).

The FEAR unit is composed of four basic components:

1. **Coil wire.** Any gauge insulated wire can be used, but the finer gauge wire available the better (i.e., bell wire, transformer wire, starter solenoid wire, speaker wire).

2. **Coil core.** Any thin piece of magnetic, iron, or steel base metal can be used (i.e., nail, screw, M16 firing pin, hairpin).

3. **Relay armature.** Any magnetic strip of thin metal (i.e., tin C-ration can, sheet metal).

4. **Relay base.** Any nonmetallic surface on which to mount the FEAR unit (i.e., wood, plastic, fiberglass).

Let's say, for instance, you have the following items at hand: bell wire, nails, large C-ration can, and a piece of wood. See Figure 4 and the following instructions:

1. Use your bayonet or the saw blade on your knife to cut the C-ration can into two strips 3 inches to 6 inches long and ½ inch to ¾ inch wide. Bend the strips so they are fairly straight.

2. Carefully and evenly wrap the bell wire around one of the nails at least one hundred times. Cut, and scrape the insulation off each end of the bell wire.

3. Mount the nail in the center of the piece of wood and pound it into the base securely.

4. Bend one of the metal strips into the shape of a Z. Then mount it over the top of the coil and secure the end to the base.

5. Bend the other strip into a Z shape. Then mount it on the wood base, facing the other strip over the coil.

You have constructed a simple electromagnetic relay. Put two more nails into the wooden base, and connect your coil wires to them. Connect a wire to the headphone or speaker connections on your receiver to the two terminals on the

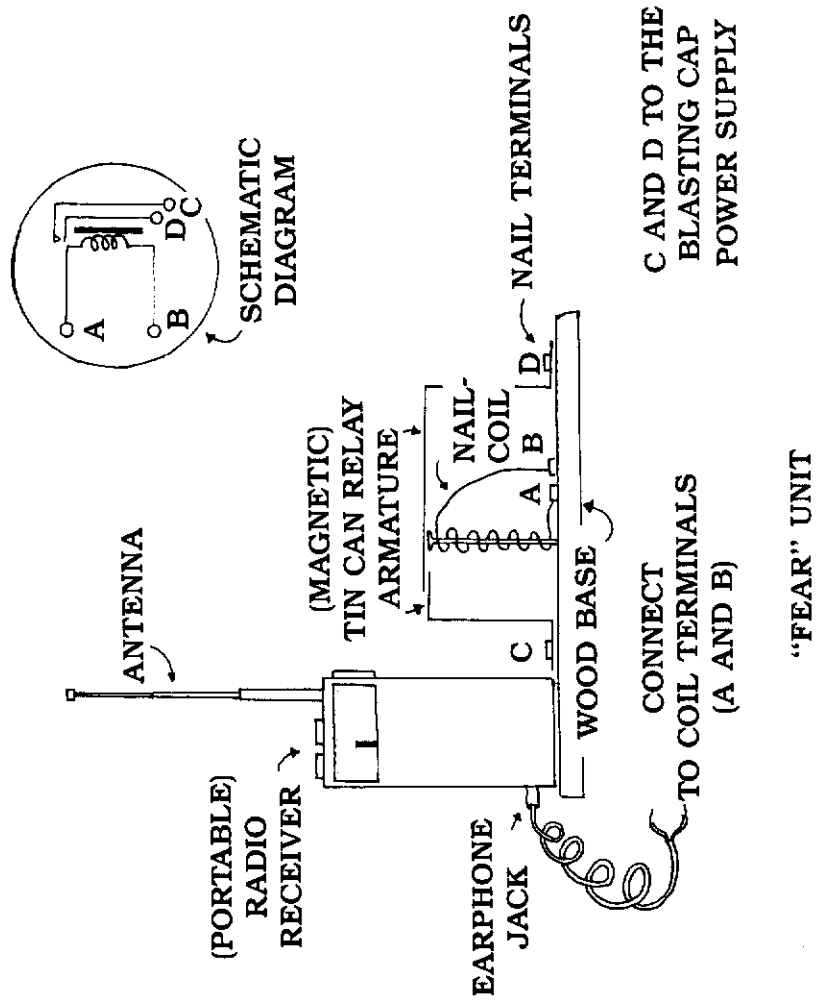


Figure 4

board. Tune the receiver to a station and turn the volume control up until the coil has enough current to pull the armature down to the head of the coil core nail. Adjust your two armatures on the board so that when one is pulled to the nail core it touches the other armature as well. Connect the battery for the demo charge to one terminal of the armature and connect the demo wire to the other terminal. When the audio signal from the receiver passes through the coil wires, it causes the armatures to connect and thereby close the electrical circuit to the explosives, detonating the charge.

Any available transmitter/receiver combination that is used for voice or tone communications can be used with the FEAR unit. Carefully adjust and test this unit prior to emplacement. If weather conditions are wet, place the FEAR unit and the receiver in a sheltered area, such as an ammo can or plastic-wrapped box. Keep in mind that if you put your receiver in a metal enclosure, you should place the antenna outside the enclosure so it will receive the transmission.

The FEAR unit has several disadvantages that must be very carefully considered before emplacement. Because the unit simply requires an audio signal to detonate, it is possible to have the unit unintentionally detonated before you wish, if a strong enough transmission occurs on the radio frequency to which the receiver is tuned. It is important to avoid any frequency that has even infrequent use for this reason. Keep your antenna wire short, and place the unit in the armed position as close to detonation time as possible.

A good fail-safe technique when using the

FEAR system is to design two relays connected to two receivers on separate frequencies. Relay 1 switches on the receiver to relay 2, which provides you with a safety margin in that one signal must be received to arm the unit and another to detonate the device.

You could just wire a timer into the system at any convenient point. This would at least allow for get-away time.

The FEAR system is a quick-fix solution to an RC problem that may occur when you are unprepared to provide Command with a safer, more advanced method of RC detonation. It should also be pointed out that the FEAR system is very easy to defeat should the target suspect that such a device is in place and be able to estimate its location.

This technique should also be kept unavailable to most indigenous forces due to its simple construction and design. These types of improvised skills have come back to haunt team members who have taught them to certain "friendly" operatives who then provided these techniques to hostile forces.

board. Tune the receiver to a station and turn the volume control up until the coil has enough current to pull the armature down to the head of the coil core nail. Adjust your two armatures on the board so that when one is pulled to the nail core it touches the other armature as well. Connect the battery for the demo charge to one terminal of the armature and connect the demo wire to the other terminal. When the audio signal from the receiver passes through the coil wires, it causes the armatures to connect and thereby close the electrical circuit to the explosives, detonating the charge.

Any available transmitter/receiver combination that is used for voice or tone communications can be used with the FEAR unit. Carefully adjust and test this unit prior to emplacement. If weather conditions are wet, place the FEAR unit and the receiver in a sheltered area, such as an ammo can or plastic-wrapped box. Keep in mind that if you put your receiver in a metal enclosure, you should place the antenna outside the enclosure so it will receive the transmission.

The FEAR unit has several disadvantages that must be very carefully considered before emplacement. Because the unit simply requires an audio signal to detonate, it is possible to have the unit unintentionally detonated before you wish, if a strong enough transmission occurs on the radio frequency to which the receiver is tuned. It is important to avoid any frequency that has even infrequent use for this reason. Keep your antenna wire short, and place the unit in the armed position as close to detonation time as possible.

A good fail-safe technique when using the

FEAR system is to design two relays connected to two receivers on separate frequencies. Relay 1 switches on the receiver to relay 2, which provides you with a safety margin in that one signal must be received to arm the unit and another to detonate the device.

You could just wire a timer into the system at any convenient point. This would at least allow for get-away time.

The FEAR system is a quick-fix solution to an RC problem that may occur when you are unprepared to provide Command with a safer, more advanced method of RC detonation. It should also be pointed out that the FEAR system is very easy to defeat should the target suspect that such a device is in place and be able to estimate its location.

This technique should also be kept unavailable to most indigenous forces due to its simple construction and design. These types of improvised skills have come back to haunt team members who have taught them to certain "friendly" operatives who then provided these techniques to hostile forces.

Chapter 4

Touch-Tone Encoding and Decoding System

As you learned when you constructed the FEAR unit, a relay responds to an electrical signal from the audio output of a receiver, which switches on the electrical circuit that detonates the charge. The problem with the FEAR unit is that *any* signal on your receiver's frequency can cause the relay to switch on.

In order to make an RC system much more reliable, it is necessary to put a device between the receiver and the switching section that will wait for a specific signal on the receiver's frequency before switching the charge voltage to the blasting cap.

There are several methods available to accomplish this. For our purposes, we are going to construct a tone encoding and decoding system based on the touch-tone telephone system used in the United States.

DUAL TONE MULTI-FREQUENCY (DTMF) GENERATOR

The touch-tone signal coming from a telephone keypad is known as a *dual tone multi-frequency* (DTMF) signal. When you press one of the twelve

buttons on your phone, you send a specific tone down the phone line to the central office switching system.

An audio tone is actually an AC voltage. The pitch of the tone is known as the frequency of the AC signal. Audio tones are in the frequency of 20 to 20,000 hertz (Hz). The AC coming out of your wall socket has a frequency of 60 Hz. This low frequency can be heard by putting an AM radio close to a fluorescent light. This sound is known as *AC hum*.

The standard touch-tone phone generates two different frequencies each time one of the keys is pressed. These dual tones are the basis for our tone encoding and decoding system for a reliable DTMF RC system.

The frequencies of these dual tones on your telephone keypad are as follows:

Character	Frequency 1	Frequency 2
1	697 Hz	1209 Hz
2	697 Hz	1336 Hz
3	697 Hz	1477 Hz
4	770 Hz	1209 Hz
5	770 Hz	1336 Hz
6	770 Hz	1477 Hz
7	852 Hz	1209 Hz
8	852 Hz	1336 Hz
9	852 Hz	1477 Hz
0	941 Hz	1336 Hz
*	941 Hz	1209 Hz
#	941 Hz	1477 Hz

There are several methods of generating these tones in the field for use in an RC system. The easiest method is to purchase a touch-tone generator (Radio Shack model #43-139 is battery-operated and inexpensive). The team

communications NCO should have an audio-tone generator capable of producing any of these frequencies as well.

DUAL TONE MULTI-FREQUENCY (DTMF) DECODER

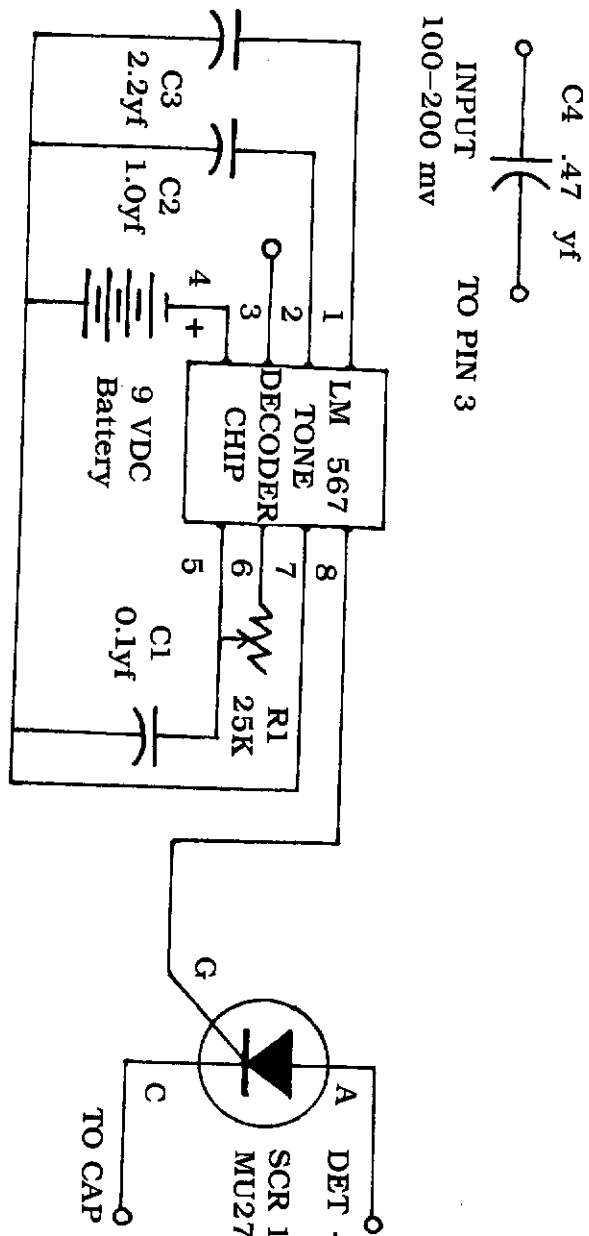
Use the DTMF generator on the transmit side of the RC system and a DTMF decoder on the receive side. Without going into a long technical description of how the DTMF decoder functions, suffice to say that this device is capable of recognizing specific tones and rejecting any other tones or signals.

The DTMF decoders discussed here also include an electronic switching system. Thus the need for a relay between the decoder and the detonation system is eliminated.

There are several DTMF decoders available. If you are going to use just one tone as your signal source, you can build a single-tone decoder quickly and inexpensively. Radio Shack has this circuit all on one tiny integrated circuit (IC) chip, called an LM567 (chip part #276-1721). It runs off a 9-volt battery for several weeks and retails for $1.99.

If you want to use several different tones for your blast detonation, which is advisable in a heavily congested urban area, then a complete DTMF receiver is recommended. Radio Shack has this circuit already on an IC chip as well, the SSI 202 (chip part #276-1303). It runs on 5 volts DC and retails for $12.95.

Both decoder packages include excellent documentation. Simply hook the audio output from your receiver to the input on the decoder. Adjust your volume control to low. Connect your charge



See also "Archer Semiconductor Reference Guide" for more useful circuits using this chip (i.e., DTMF Decoder, oscillator).

Parts List

C1	0.1yf	(RS 272–1069)
C2	0.1yf	(RS 272–1432)
C3	2.2yf	(RS 272–1435)
C4	.47yf	(RS 272–1433)
R1	25K	(RS 271–336)
LM567		(RS 276–1721)
SCR	1	(RS 276–1067)

Variable Frequency Tone Decoder

R1 × .1 = Input Frequency (Hz)
SCR Switching

Check R1 and set ohms out of the circuit with VOM.

Covers 500–2500 Hz @1–200mv RMS

Figure 5. Tone Decoder Circuit

detonation wire to the output switching terminals on the decoder and you are operational.

Figure 5 illustrates a simple-to-construct tone decoder that is capable of switching on with any frequency from 500 to 2,500 Hz.

The DTMF RC system is the most reliable means to safely and effectively detonate an explosive device. If Command requires detonation of several different explosive devices at specific times and/or locations, the DTMF RC system is extremely useful for this application. The single-tone receiver and a tone generator can easily be used to detonate twelve different explosions throughout your area of operations.

This is of particular use in base camp perimeter security applications as well as in convoy ambush missions.

The demo personnel on the team should have several DTMF units available to them for field use as part of their basic loads. These devices are lightweight and consume very little current.

Because the DTMF receiver is nonmechanical and small in size, it is both very reliable and difficult to detect. A well-installed and carefully emplaced DTMF system is also very difficult to defeat using standard electronic countermeasures (ECM). The tone transmission required to detonate a DTMF RC system need be only 100 milliseconds (1/10 of a second). Thus it is virtually impossible for your transmission to be located using radio direction finding (RDF) equipment.

The remainder of this field manual deals with specific types of consumer electronic devices available to you for modification. These devices are not limited to those described in this manual. Other devices that consist of a transmitter and receiver assembly can also be used to effect RC detonation. Experimentation and modification are all that are generally required for such devices as garage-door openers and model plane and car control systems.

Chapter 5

Modification of a Cordless Telephone

The U.S. market has been saturated with cordless telephone units over the past five years or so. These devices are available in any department store or consumer electronics store.

A cordless phone is actually a 2-channel (Duplex) transceiver. It generally operates on the frequency of 49 megahertz (MHz). These devices come from the manufacturer with a maximum range of approximately 1,000 feet under ideal conditions. This chapter will explain how you can effectively increase this range in excess of one mile, as well as how to modify the unit to function as an RC device in less than an hour.

A cordless phone system is composed of two components—the base unit and the hand-held portable unit. The base unit plugs into the phone line and a wall outlet. It transmits and receives the phone conversation from the portable unit over the phone lines. The base unit also has facilities to recharge the hand-held portable unit when it is not in use.

The hand-held portable unit uses rechargeable nickel-cadmium (ni-cad) batteries to operate. Most of the portable units are designed to run on 4.5 volts DC. Since the ni-cad batteries will

only function for about six to eight hours on a full charge, they are of little use for the application we have in mind.

Although any cordless phone can be modified using the techniques in this manual, it is best to obtain the type of unit that has the "paging" function. This allows you to eliminate several steps in the modification process.

The following modifications will be done on the cordless phone unit you have selected:

1. Modification of the power supply assembly on the base unit to function from batteries instead of AC.
2. Modification of the remote unit to operate on standard D-cell batteries for longer operation time.
3. Modification of the paging section on the remote unit to function as the detonation switching and blasting cap power source.
4. Modification of the base and remote unit's antenna to eliminate the whip antennas (which tend to break under normal field use) and greatly improve the range of the unit with an easy-to-conceal, thin-wire antenna assembly.
5. Installing both base and remote units into a shock-resistant, waterproof housing for extended field use.

Before attempting to perform these modifications, it is very important that you test the phone system out to ensure that you have a working unit. This is particularly important if you purchased the unit secondhand. The most common problem with these units seems to be weak or dead batteries in the remote unit. The second most common failure is that antenna connections on the remote are loose, or that the system

is simply out of range. Once you have ensured that you have an operational unit, then you are ready to begin.

MODIFICATION OF THE BASE-UNIT POWER SUPPLY

The procedure outlined in Chapter 2 of this manual is the best means to accomplish this modification. Since you will only be operating the base-unit assembly as a transmitter for very short durations, the power source can be of low current variety, such as AA cells hooked in series to the required voltage (1.5 VDC per battery cell). This also reduces weight. The batteries should be placed in a battery holder for reliability and ease of replacement. The following table suggests several different battery-box units for AA cells where different voltages may be required (available from Radio Shack):

Voltage Required	Cells	Part #
3.0 VDC	2	270–382
4.5 VDC	3	270–383*
6.0 VDC	4	270–383
9.0 VDC	6	270–387**
12.0 VDC	8	270–387

*This is actually a four-cell unit. Modify it for three cells by shorting out one of the cell locations by connecting the + side to the – side for that cell location with a wire.

**This is actually an eight-cell unit and you can modify it as stated above.

You can also reduce the weight of the base unit by removing the metal chassis on which the circuit board is mounted, as well as removing the power transformer, power cord, and recharger

terminals. This will reduce the weight of the base unit by more than 50 percent.

Mounted on top of the base unit case is a paging switch, which is used to notify the user of the remote unit that he is needed at the base location. This switch is called a *single-pole single-throw* (SPST) momentary switch. Clip the two wires from the terminals of this switch assembly, and replace the switch with a good, durable SPST momentary switch. Radio Shack has several available; model #275-609 is an excellent choice, though it requires a 1/2-inch hole to be drilled in the case of your unit. This switch is your detonation button, which will be mounted on the outside of your case assembly.

The last modification to your base unit power section is a power switch. This can be any SPST switch you have, but it should be durable and able to withstand exposure to the elements. It is recommended that you use a panel-mounted toggle switch for this reason. Radio Shack model #275-612 is good, and it requires a 1/4-inch hole to be drilled into the case of your unit. The power switch will function as your "arming" switch to the explosive device.

Test the completed unit assembly with the remote hand-held unit to ensure that it is operating correctly. Also, verify that the paging function works well; make sure it will set off the cap.

MODIFICATION OF THE REMOTE UNIT POWER SUPPLY

This is a relatively simple procedure. Open up the unit by removing the small screws on the bottom of the remote case. Locate the ni-cad batteries, which are generally located on the back

of the circuit board at the bottom of the chassis assembly. The batteries are almost always rectangular and about 1/2-inch thick. The operating voltage of the ni-cads is usually printed on the battery case. If not, check the voltage with the VOM. It is most often 4.5 to 6 VDC. The ni-cads in these units are usually replaceable, so simply slide them out of the terminal block. If the batteries are soldered into the unit, either clip or unsolder them.

Because the ni-cads are only designed to run a few hours, it is necessary to replace them with high-current D cells. The remote receivers tested with D cells have operated more than ten days in the stand-by receive mode. The D cells should be placed in battery holders. The following are the part numbers from Radio Shack for a variety of different voltages:

Voltage	Cells	Part #
1.5	1	270–403
3.0	2	270–386
4.5	3	270–389*
6.0	4	270–389

*This is actually a four-cell battery holder. You can modify it for three cells by shorting out one of the cells as described earlier.

You can reduce the weight and bulk of the remote unit by removing the circuit board from the chassis mount on the case, and then removing the touch-tone keypad, the earphone, and the microphone. The ringer device on the remote is a small, round electronic buzzer close to the microphone on the circuit board. If you are not sure where it is located, test the page function on the base and listen to the ringer beep. Discon-

nect the ringer from the circuit board and attach two pieces of hook-up wire to the terminals. This is going to be your detonation-wire hook-up point.

Connect the two ringer wires to an *enclosed* 1/8-inch jack (Radio Shack model #274-297, which requires a 3/16-inch hole). This will allow you to plug in your detonation wire directly from the chassis case.

The last modification needed on the power assembly off your remote unit is a power switch. Again, it is advised that you use a toggle-type SPST switch (Radio Shack model #275-612).

Test the completed modification by pressing the base unit paging switch and connecting your VOM to the two ringer terminals on the enclosed 1/8-inch jack. You should read anywhere from 1.5 to 3 volts when the page button is depressed.

You now have a cordless phone modified to operate on DC that will ignite a blasting cap when the detonation (paging) button is depressed. Now all that is left to do is increase the effective range of the unit, encase each unit in weatherproof housings, and then perform a final field-test before deployment.

MODIFICATION OF THE BASE AND REMOTE UNIT ANTENNAS

Warning: The procedures outlined in the following section will render the cordless phone to be in violation of FCC rules that govern such devices. Conviction of possession or operation of an unlawful transmission device can lead to fines and/or actual imprisonment in the United States.

The radio transmitter used in a cordless phone operates on a frequency of 49 MHz. The antenna

supplied with the typical unit has a length of 15 inches to 28 inches. The antennas are designed for use in close proximity to each other.

The proper way of determining the most effective length for a radio antenna is by taking the frequency wavelength in megahertz and dividing it into the number 936 to get the approximate length in feet for a full-wave vertical antenna. A half-wave antenna would require the frequency to be divided into 468, and a quarter-wave antenna would be divided into 234. Thus the 47 MHz frequency would be best served by the following lengths of vertical antennas.

- Full Wave (936/47 = 19.914893) or (approx.) 20 ft.
- Half Wave (468/47 = 9.9574468) or (approx.) 10 ft.
- Quarter Wave (234/47 = 4.9361702) or (approx.) 5 ft.

A 49 MHz unit would require the following lengths (cordless phones in the United States and overseas usually use one or the other):

- Full Wave (936/49 = 19.10204) or (approx.) 19 ft.
- Half Wave (468/49 = 9.551020) or (approx.) 9.5 ft.
- Quarter Wave (234/49 = 4.775510) or (approx.) 5 ft.

To get the maximum range from the cordless phone transmitter, it is necessary to replace the somewhat fragile whip antenna with a more durable and portable wire antenna. On each unit, you simply disconnect the wire leading to the antenna and connect it to another enclosed

1/8-inch jack (Radio Shack model #274-297). Short all three terminals on this jack and connect the antenna wire to it.

Since the ideal length for your 49 MHz transmission is a 20-foot antenna, you connect a 20-foot piece of wire to a 1/8-inch plug (Radio Shack model #274-286) and you are operational. Radio Shack makes a 1/8-inch plug already connected to 20 feet of thin black wire (model #42-2462), which is sold as a stereo headphone extension cord; this works very well.

If for tactical reasons the 20-foot length is not practical, use either a 10-foot or 5-foot antenna on either unit. Perhaps you will find it useful to use a 20-foot antenna on your receiver and a 5-foot antenna on your detonator base control unit. This works very well, and can produce detonation up to one mile away over flat terrain under good conditions.

Install the receiver antenna as straight in the air as possible. Place the wire over a tree or down the side of the target building. The advantage of a vertical antenna over a horizontal antenna is that the vertical antenna can receive equally well from any one direction, giving the detonation operator more freedom of movement. Consult with your communications specialist team member for other suggestions in antenna design and installation.

To test the system, short out the detonation switch with a piece of wire and walk as far away as you can with the receiver while still getting a reading at the ringer terminals.

INSTALLATION OF BASE AND REMOTE UNITS IN WEATHERPROOF HOUSING

The units should now be ready for placement

in a suitable enclosure. The conditions under which the equipment will most likely be used will determine how the system is enclosed. Let's assume that the units will be used in a wooded or jungle environment, exposed to extreme levels of heat and humidity, and subjected to typical abuse consistent with a standard tactical field operation.

The first concern is to protect the circuitry from shock or damage from weather elements. Under these conditions, a sturdy metal enclosure is ideal. An ammo box, weapons case, or any other sealed metal enclosure is suitable for this purpose. Radio Shack has several types of metal enclosures in its 270 stock number series that will also work well.

Select the unit based on the size of your complete system. After drilling holes in the enclosure for the jacks, switches, and cables, seal the inside of the installed switch or jack assembly with epoxy or caulking compound. This will keep the internal electronic circuitry dry if the unit becomes exposed to rain or immersed in water.

Before installing the circuit-board assembly into the weather-sealed enclosure, it is a good idea to place a paper towel in the enclosure, reseal it, and then submerse the device in water for at least 24 hours. If after this period the paper towel is still dry, *then* you have a weatherproof enclosure.

APPLICATION NOTES FOR CORDLESS PHONE MODIFICATION

System advantages:

1. Both receiver and transmitter are *crystal-controlled*. This allows for steady, consistent reception even under adverse field conditions

and battery degradation.

2. *Durability*. The remote unit circuitry is surprisingly well constructed and the device is designed for a bit of abuse by the consumer, both indoors and out.

3. *Tone-controlled*. In a field environment, the possibility of accidental detonation is unlikely.

System disadvantages:

1. *Frequency*. Many countries use the 49 MHz frequency for tactical field communications. Increased traffic on this frequency can make the unit susceptible to both electronic countermeasures (ECM) and radio frequency interference (RFI).

2. *Usage*. Because of the proliferation of these devices in the urban environment (as well as other tone-controlled devices also operating on this frequency), the unit is best suited for remote field applications to avoid accidental detonation.

3. *Single channel*. The unit can not be used for multiple field detonation and is best suited for short-range sabotage and assassination mission deployment.

Chapter 6

Modification of a Citizens Band Radio

The standard U.S.-manufactured citizens band radio is available virtually anywhere in the country. It is inexpensive and easy to operate. Although there are no licensing requirements to own or operate these devices, their use is still controlled and regulated by the FCC. Federal Regulation Code No. 47, subpart D, part 95 of the FCC rules governs the use of this equipment.

A standard 40-channel, 5-watt CB radio will broadcast voice transmissions several miles, depending on the weather conditions, antenna type and installation, and the type of unit you own. The maximum range at which you may operate a CB radio is 155 miles, which can be accomplished with a good antenna system. For practical purposes, the range for walkie-talkies or basic, inexpensive mobile units will be generally limited to 5 to 12 miles.

There are several manufacturing companies that offer long-range "linear" amplifiers for citizens band radios. Possession or use of these devices will result in prosecution by the FCC (it should be noted that the FCC has a very sophisticated and effective RDF capability). If you want your unit to have a range of several

hundred miles outside the U.S. border, several sources for linear amps are described at the end of this section.

The CB radio operates in the 27 MHz frequency range. The forty channels on the radio are each a specific frequency. These frequencies are listed below for use by the communications NCO, should the team's high frequency (HF) radio be used in conjunction with these units in the field.

CITIZENS BAND RADIO CHANNEL FREQUENCY CHART.

Channel	Frequency	Channel	Frequency
1	26.965 MHz	21	27.215 MHz
2	26.975 MHz	22	27.225 MHz
3	26.985 MHz	23	27.255 MHz
4	27.005 MHz	24	27.235 MHz
5	27.015 MHz	25	27.245 MHz
6	27.025 MHz	26	27.265 MHz
7	27.035 MHz	27	27.275 MHz
8	27.055 MHz	28	27.285 MHz
9*	27.065 MHz	29	27.295 MHz
10	27.075 MHz	30	27.305 MHz
11	27.085 MHz	31	27.315 MHz
12	27.105 MHz	32	27.325 MHz
13	27.115 MHz	33	27.335 MHz
14	27.125 MHz	34	27.345 MHz
15	27.135 MHz	35	27.355 MHz
16	27.155 MHz	36	27.365 MHz
17	27.165 MHz	37	27.375 MHz
18	27.175 MHz	38	27.385 MHz
19	27.185 MHz	39	27.395 MHz
20	27.205 MHz	40	27.405 MHz

*Channel 9 is designated "Emergency Use Only" by the FCC.

Modification of the citizens band radio is simple and straightforward. Using your tone-encoder module (such as Radio Shack model #43-139), place the speaker of the tone-encoder to the microphone of the radio. Test this procedure with another radio some distance from your unit to verify that the tone is transmitted clearly and at a sufficient volume. It should be noted that digital tone transmissions are illegal on the citizens band radio frequencies, so keep these transmissions short.

Key the mike of the radio and press one of the twelve tone buttons on the encoder to send the DTMF transmission to your receiver.

The receiver unit has a speaker or headphone jack on either the front panel or the back of the unit. This is usually a 1/8-inch plug. Connect your DTMF receiver or tone-controller module to the jack and you are operational. Since the CB radio equipment has other uses besides RC detonation, it is suggested that you place your receiver well out of the blast zone. Also, always keep your tone-encoder separate and unattached to the CB mike to avoid confiscation by the FCC for sending tone over the airwaves.

The following list of firms and organizations in the United States can provide you with kits, plans, and instructions for the construction of linear amplifier units that can (illegally) increase your effective range to several hundred miles:

CBCI
P.O. Box 31500
Phoenix, AZ 85046

CB Operators of America
11 Colin Avenue
Uniontown, PA 15401

Pan-Com
P.O. Box 130
Paradise, CA 95967

Huntley Radio
11721 Eureka Road
Edinboro, PA 16412

The following magazines also have advertisers for CB radio modifications and equipment:

Radio Electronics
P.O. Box 51866
Boulder, CO 80321-1866

Popular Communications
76 North Broadway
Hicksville, NY 11801

Chapter 7

Modification of an FM Wireless Microphone and Portable Receiver

The standard FM portable radio receiver, such as the "Walkman" type or AM-FM portable, is a lightweight, reliable battery-operated receiver generally capable of receiving FM transmissions in excess of thirty miles from the transmitter.

The FM wireless microphone is a small transistorized radio frequency (RF) transmitter which operates on the 88–108 MHz FM frequency band. This device is available from a variety of suppliers, including Radio Shack (a list of suppliers is provided at the end of this section). These units are usually priced under $50 and usually operate on a standard 9-volt battery. The effective range of these devices is usually from 300 feet to—with modified antennas, etc.—more than 3 miles. It is, however, against FCC regulations to operate these devices at ranges in excess of one mile (Federal Regulation Code 47, part 15 contains the regulations for these devices).

Using your DTMF encoder and decoder assembly with these devices is also in violation of FCC rules. However, the unit you can construct using these transmitter and receiver combinations can be as small as a cigarette lighter and is very suitable for both urban and tropical

UCW operations. Use of these devices in the United States is not recommended.

Of the units available for use in this application, the DECO Industries model WAT-50 miniature FM transmitter is the most efficient, and it is easy to build from kit form. This device is about the size of a quarter and will broadcast DTMF pulse well over a mile to a standard FM receiver. The WAT-50 also has another advantage over most of these devices in that it can transmit from 70 to 130 MHz, which allows the user to send his transmission out of the normal FM broadcast band frequencies. Using a portable aircraft receiver (Radio Shack model #12-601 is inexpensive and easy to modify), the user can avoid having his tone traffic picked up on the standard FM radios in the area.

To use the receiver-transmitter combination, simply send a tone over the transmitter with your encoder and plug your tone decoder directly into the earphone jack of your receiver.

The following is a partial list of the manufacturers of FM wireless microphone kits and units.

CAS Electronics
1559-J Amar Rd. #457
West Covina, CA 91782

DECO Industries
P.O. Box 607
Bedford Hills, NY 10507

Electronic Pursuits
1269 Broadway
El Cajon, CA 92021

Information Unlimited
P.O. Box 716
Amherst, NH 03031

Microtron
42 38th St.
Wheeling, WV 26003

RF Electronics
826 W. Valley Blvd. #135
Alhambra, CA 91803

Spy Shops International
P.O. Box 1738
Englewood Cliffs, NJ 07632

USI Corp.
P.O. Box 2052
Melbourne, FL 32902

Chapter 8

Modification of an Auto-Alarm Paging System

Auto-alarm paging systems provide the user with a "silent" alarm warning system for his car or truck. If someone attempts to hot-wire or gain entry to the vehicle the alarm sends a radio signal through the car's antenna to a beeper that the owner wears on his belt.

The devices available for modification are manufactured in the United States and Japan by several firms (Radio Shack sells two models). All these devices have similar technical characteristics and are suitable for modification.

The typical auto-alarm page transmitter operates from the car's 12 VDC battery. It has a range of two to eight miles, and is priced well under $100 retail. The units usually have one or two pagers with the system; extra pagers are priced around $30 each.

These devices are generally 4- to 5-watt, crystal-controlled, 8-bit digital transmitter and receiver assemblies. They are built to operate in the frequency of 27.145 MHz in the United States. According to FCC rules governing these devices, these units may not have an operating output power in excess of 5 watts. It should be noted that the frequency of 27.145 MHz is actu-

ally between CB channels 15 and 16. These devices can be illegally attached to any of the standard linear amplifiers for a range of several hundred miles.

The typical pager alarm unit can operate 3- to 9-volt batteries for several days. These units are durable and very easy to conceal.

All the units available on the U.S. market use a digital binary-coded signal to set off the specific receiver used with each individual alarm. Most of these units have a small switch assembly on both the transmitter and receiver. These switch assemblies are generally 8-pin dual in-line package (DIP)-type, two-position switches, which the operator sets with a pen or thin-tipped screwdriver. The standard 8-pin DIP switch assembly provides the user with 256 different combinations of binary signals to select from. When purchasing one of these units, it is best to determine how many different tone combinations are available. Radio Shack model #49-791 has 256 possible combinations and is ideally suited for this application due to the "Page" button already installed on the front panel.

Although this type of binary switching system is not a true DTMF-type device, it is nonetheless a digital transmission of PCM and is very reliable to use in both the field or an urban environment.

The typical receiver available with these devices will have a small rod or wire antenna built into the case of the pager. These antennas are generally between 2½ inches and 4 inches long. We will modify this antenna connection for both increased range and a higher degree of reliability in receiving the binary tone transmission from the transmitter. It is suggested that you purchase at least six extra receivers for your unit so that you can modify them all at once, as

well as have the capability of a multichannel RC detonation unit once you become operational with the system.

The standard auto-alarm page system uses the same basic technical basis for operation as the devices used by the U.S. Army Special Forces Radio Detonation Unit, issued to SF demo personnel for team level radio detonation in the UCW AO. These units are digital multichannel high-frequency transmitter and receiver assemblies enclosed in weatherproof housings. They are used to detonate several different explosive devices at different locations within the range of the unit transmitter.

The weatherproof 1.5-volt D-cell-operated receiver has three terminals on top of the case. The demo operator connects a small piece of wire to the antenna terminal and the demo charge wires are connected to the other two terminals.

The transmitter has a stainless steel whip antenna enclosed in the handle of the transmitter case. A bank of numbered rotary "thumbwheel" switches for selecting the specific receiver and a "detonation" transmission switch are mounted on the front panel of the transmitter unit. These units are crystal-controlled and can operate on a variety of frequencies (these various frequency allocations are, of course, classified). This unit has been in use for some time by SF team members throughout the world, and they have had excellent results with them in the field.

The device that we are going to construct will function in the same manner as these SF units. Of all the consumer electronic devices available to you for modification, the auto-alarm page system is by far the most reliable, and it is easy to modify and use for standard RC detonation

of multiple targets.

The following modifications will be performed on the auto-alarm paging system to make the device operational as an RC detonation unit:

1. Modification of the transmitter unit to operate on D or AA cells for tactical field use.
2. Modification of the receiver unit (pager) to operate on D cells for extended emplacement.
3. Modification of both transmitter and receiver assemblies antenna connections (with wire antennas) for extended range.
4. Installation of both units in weatherproof enclosures for tactical field use.

It should be stressed at this point that most of the devices used for auto-alarm paging systems are somewhat inexpensive. There is, however, a great number of possible differences between individual makes and models. The following criteria should be followed when selecting an alarm system for modification:

- Minimum range of transmission of two miles
- Large number of possible tone combinations
- "Page" button on front panel
- 12-volt negative ground
- Metal case for transmitter unit
- Minimum power output of 4 watts

MODIFICATION OF THE BASE UNIT POWER SUPPLY (TRANSMITTER)

The transmitter unit is generally designed to operate from a car battery, therefore operating on a 12 VDC power source. In order to use the transmitter base unit in the field, it is necessary to modify the connectors on the back of the unit

to allow the use of a 12-volt D-cell or AA-cell battery-box. Use Radio Shack model #270-387 for 12-volt AA cells and model #270-396 for 6-volt D cells, which means you need two for this unit.

Follow the installation instructions for placement in an automobile electric system and simply connect the two wires to your battery-box for field use. If you wish to install a power switch to the device, use a toggle switch between the positive battery lead and the battery-box. You can bypass the fuse that comes standard with these devices for field use as well.

MODIFICATION OF THE RECEIVER UNIT (PAGER) POWER SUPPLY

The receiver unit usually operates on a 9-volt battery. If you are going to be installing this unit and detonating the charge within 24 to 48 hours, this modification is not necessary. If you want this modification to operate for several weeks on the standby receive mode, use the D-cell chart in the cordless phone section.

MODIFICATION OF RECEIVER AND TRANSMITTER WITH WIRE ANTENNAS

The transmitter unit is designed to use the vehicle's radio antenna for transmitting the digital signal to the pager. The typical auto radio antenna is between 31 inches and 51 inches long and is designed for AM and FM broadcast signals. Using the formula described in the cordless phone section of this manual, the best antenna lengths for a vertical 27.145 MHz antenna are as follows:

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- Full Wave (936/27.145 = 34.481488) or (approx.) 34½ ft.
- Half Wave (468/27.145 = 17.240744) or (approx.) 17¼ ft.
- Quarter Wave (234/27.145 = 8.620372) or (approx.) 8½ ft.
- Eighth Wave (117/27.145 = 4.310186) or (approx.) 4¼ ft.

Modification of your base and receiver antennas is very easy. Simply connect the desired length of wire antenna to the antenna connection on the back of the transmitter, or if you prefer, connect the transmitter to a standard CB mobile antenna for increased range.

The pager receiver has an internal antenna. Open up the unit with your screwdriver and locate the metal rod or wire antenna mounted on the side of the circuit board. Unsolder this antenna from the circuit board and connect the wire to an enclosed 1/8-inch jack. Then connect a plug to your antenna wire and you are operational. Test the completed unit by driving a distance from the transmitter with it left in the "page" mode. Turn your pager on and off frequently to determine the effective range.

PLACING THE COMPLETED UNITS IN ENCLOSURES

The desired enclosure is again based on your mission and your area conditions. If you are going to use the unit in an urban environment, it can be camouflaged to appear to be a common radio receiver. If the mission requires the unit to be used as an assassination device for a target operating a motor vehicle, use the vehicle's radio antenna for the receiver antenna and, obviously, mount your receiver and charge underneath the seat of the target occupant.

If, for tactical or intelligence reasons, you wish for the unit to be destroyed in the blast, put the receiver in a plastic bag with sufficient white phosphorous or a 50 percent mixture of potassium nitrate (saltpeter) and sugar, and place the receiver directly on top of the charge. It is further advised that you use a very thin strand of bell wire for your antenna.

This modified alarm paging unit has numerous advantages over most of the units described in this field manual. Because of the ease of modification, it is suggested that you keep the unit in its original unmodified condition until you are ready to deploy the device. This eliminates a legal problem should you be discovered with this common consumer device in your possession.

The applications for this unit are virtually endless. The device can be used in a variety of different RC detonation missions and is perhaps the easiest to modify and operate. Be advised that the use of the unit's operating frequency for any application other than its intended purpose is prohibited by law.

Chapter 9

Modification of a Wireless Intercom and Toy Walkie-Talkie

The standard "hands free" intercom radio used by motorcycle enthusiasts, as well as the typical children's toy walkie-talkie, operates on the 49 MHz frequency, similar to the cordless phone described earlier.

These battery-operated devices have a typical range of about one-quarter mile. The range can be extended with the same type of wire antenna described earlier. These devices can be used with your DTMF unit and, because of their low cost, are best suited for short-range assassination missions where the unit will be destroyed in the blast. These devices are available in very small packages; the batteries are generally good for six to ten hours of continuous use.

The tactical limitations of these devices are outlined in the cordless phone section. Use of these devices with the DTMF RC units is not suggested in the urban environment, because cordless phone users dialing out from their remote units will be sending DTMF signals over the 49 MHz frequencies, and it is technically feasible that they could detonate your charge if they hit the right code combination.

This type of unit is best suited for quick field

use in a remote environment at close range. It is certainly not the most suitable unit to use, but it is discussed here primarily to enable its deployment if it is the only type of unit available for RC detonation.

Chapter 10

Modification of a Radio Paging System

Radio pagers are often used by professionals to keep in touch with their offices while in the field. These devices are very common in any urban environment throughout the world.

Most of these devices are accessed through a phone number that is dialed from any touch-tone phone. The phone call connects to a radio transmitter, which sends a digital signal over the air. The specific pager (or beeper) demodulates the signal and sends current to the tiny electronic beeper on the circuit board, which then sounds off, notifying the user that he has a message back at his office.

Radio page devices can operate on numerous frequencies. Most operate in the 155 to 165 MHz frequencies throughout the world. These tiny VHF receivers have one specific application in RC detonation work—Command may have a need to assassinate a specific target in an urban technological area, such as a foreign capital. The major metropolitan areas of most foreign countries all have these radio paging units in place.

By placing the unit and a suitable charge in proximity to the target, or where intelligence dictates the target will be at a specific time, it is

possible to be out of the country prior to detonation. This provides Command with the capability of safe emplacement of the charge, selective detonation from a long distance using the telephone system, and extraction of personnel from the occupied area prior to detonation, thus eliminating possible capture after the assassination is complete and forces are mobilized.

Modification of a radio pager is quite simple. It is suggested that you perform this modification as close to your departure time as possible. Open the unit up and locate the small beeper unit inside. Unsolder this device and connect two wires to the circuit board where the beeper was connected. Connect these wires directly to your blasting cap connections. (**Note:** For use with military-grade blasting caps, use a 5 VDC relay at the page terminals. Connect the battery and blasting cap to the switching terminals on the relay to provide 1 amp for one second.)

It is suggested that you get the pager several days prior to deployment so you can test the unit for false signal reception. Once you have determined that the unit is not at all sensitive to false alarms, then you can confidently arm and emplace this unit.

The best place to locate these units and possibly even "requisition" one is at a major metropolitan hospital in your target area. The pager unit generally has the activation telephone number labeled on the side or back of the device.

The pager is small and reliable, and operates for several days on fresh batteries. The target can be effectively hit using this device when all personnel associated with the mission are thousands of miles away from the target area. Although use of the radio paging system for

RC detonation work is somewhat limited, this procedure has been used by many foreign intelligence agencies and terrorist groups in both western Europe and the Middle East for some time.

It should be pointed out that these crystal-controlled devices are relatively easy to detect due to the oscillation of the intermediate frequency (IF) stage in the circuitry. If you suspect that such a device is in use, it can be detected using standard ECM gear designed to detect hidden transmission devices.

Chapter 11

Modification of a Cellular Mobile Telephone

The cellular mobile telephone is becoming popular throughout the civilized world. These devices are made for both hand-held use and installation in vehicles. Because these devices are accessed with a telephone, the application and emplacement of these units make them suitable for use as an assassination medium, similar to the radio pager.

Cellular mobile telephones (CMTs) operate in the UHF frequencies of 800 MHz. They are short-range transceivers that operate throughout the area by transferring over to individual repeater locations or cells as the operator moves through a specific metropolitan area. Because these devices are popular with typical military and government targets, their use as assassination tools is described in this field manual.

Modification of this device is very simple. Open the handset of the unit and connect your blasting-cap wires to the ringer terminals. Disconnection of the ringer is not necessary. The voltage to the ringer is quite sufficient to detonate the cap. A small charge placed in the phone unit should be more than sufficient to cause mortal trauma to someone in close proximity to

the unit in an enclosed vehicle.

Portable hand-held units provide mobility and more selective emplacement of the device for long-range assassination missions. Be aware that these devices can also be detected using standard ECM equipment.

Chapter 12

Using a VHF Scanner as Your Receiver

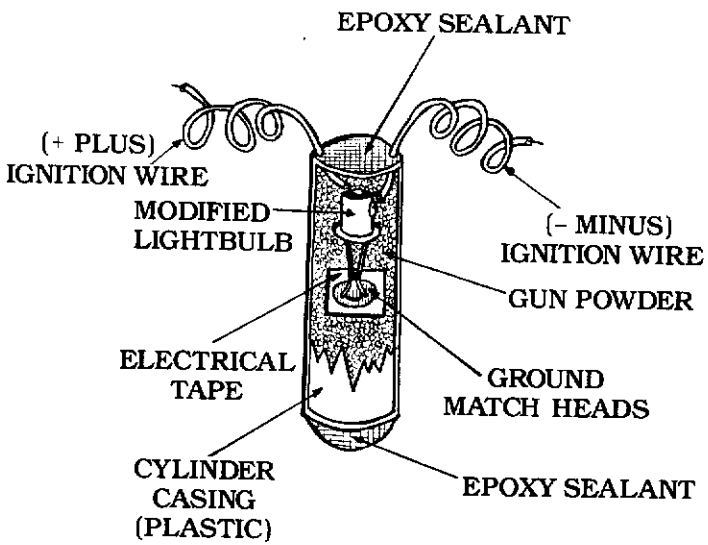
The standard VHF scanner is either crystal-controlled or operates using a synthesizer to tune a specific frequency. These common devices are very reliable. They are discussed here because of their frequency stability and sensitivity, and flexible frequency selection. By connecting your DTMF receiver or tone-control module to the earphone or speaker jack of the scanner, you can use your standard-issue VHF portable transceiver (walkie-talkie) to detonate a charge from as far away as 35 miles.

The procedure is simple. Select a frequency in the band-width capability of your team radio, and either program the scanner or insert the proper frequency crystal in the device. Then lock out all other frequencies on the scanner's channel-selection program board and you are operational.

The scanner can, of course, be modified for extended range using the antenna procedures outlined in this manual. The VHF scanner can be used for medium-range detonation when a *high* degree of reliability is desired in a heavy-congestion urban environment with a lot of radio traffic.

Several manufacturers offer single-channel or 2-channel VHF receivers that are inexpensive and very suitable for this application. Radio Shack offers an inexpensive 2-channel model, called the PRO-27, model #20-108.

Although this device can be used with most improvised munitions, it is *not* suitable for military grade C-4, or other high temp ignition required devices or compounds.



Use epoxy to seal both ends of the cylinder in place of tape, if available for a better blast detonation (also makes device waterproof).

Figure 6. Improvised Field-Expedient Electrical Detonation Device Using a Lightbulb.

Appendix A

Improvised Field-Expedient Blasting Cap

If most of your munitions are improvised from materials accessible to you in your AO, it is possible that you do not have a means of electrically detonating your demolition charges, such as a blasting cap. This section is intended to provide you with a method to create your own.

A blasting cap is an electrical device used to ignite an explosive charge. The cap usually requires from 0.5 volts to 3 volts DC to ignite. Blasting caps can also ignite from an electrical storm or even nearby radio transmission (as those personnel trained to use them can readily attest).

The improvised cap explained here is more stable in design. It will not detonate without a direct electrical charge, and it is also much less sensitive to humidity and moisture.

REQUIRED MATERIALS

- Flashlight bulb (1.5 to 12 VDC)
- Cartridge powder from M16, .45, or 9mm round; or black powder
- 5 matches
- 12 inches of hook-up wire

- One cylinder-type container (ballpoint pen, IV needle case, etc.)
- Electrical tape, solder, etc.

The flashlight bulb can be any voltage. If you wish to use a specific voltage, these Radio Shack stock numbers can be used:

Voltage	Size	Stock Number	Current Required
2.33	E-10	272-1124	270 ma
2.38	Flashlight	272-1122	270 ma
2.38	Flashlight	272-1120	500 ma*
2.47	E-10	272-1132	300 ma
3.57	Flashlight	272-1121	500 ma
4.75	Flashlight	272-1151	500 ma
4.8	Flashlight	272-1125	500 ma
5.95	Flashlight	272-1123	500 ma
6.3	E-10	272-1128	150 ma
7.5	E-10	272-1133	220 ma
8.63	Flashlight	272-1166	500 ma
12.0	E-5	272-1143	75 ma

*This is the standard PR-2 bulb issued in U.S. two-cell flashlights.

Select the bulb that uses the voltage you have available for your charge detonation. If the charge is going to be placed in an automobile, use the 12-volt bulb and the car's battery for the detonation power source.

You will need your soldering iron (or gas torch) as well as wire cutters and needle-nose pliers for this modification.

Use your needle-nose pliers to carefully break the glass around the light-bulb filament. This is a very delicate job. It is best to shatter the top portion of the glass first, and then pull away the fragments of broken glass around the base of the bulb with the pliers. Use care near the fine wire

of the filament and be sure to inspect the filament when you are finished. Use your VOM to verify that the filament is still intact by setting the VOM on Ohms and measuring the resistance of the bulb at the tip and side of the base. It should read close to 0 Ohms.

Cut your 12-inch hook-up wire into two 6-inch strips and strip the insulation back ½ inch on each end of both wires.

Warm up your soldering iron. As it heats up, use a file or a piece of sandpaper to rough up the side of the metal base of the bulb. This will ensure a good electrical connection when it is soldered.

Solder one wire to the bottom of the bulb base very carefully with a small amount of solder. Don't leave the tip on the area too long or you will melt the plastic base of the bulb. Solder the other wire to the filed or sanded area of the side of the bulb base. Again, don't leave the iron on the unit for a long time.

Once completed, test the unit again at the ends of the wires for continuity. If it tests "good," wrap the base of the bulb in one layer of electrical tape.

Using your pocket knife, scrape the heads off the matches and grind the particles into a fine powder. Put this powder in the center of a ½-inch piece of electrical tape. Lay the tip of the bulb filament on top of the match heads on the tape and cover with another ½-inch piece of electrical tape.

Test the completed unit again with the VOM before you go on to finish the cap. Now fill the cylinder tube with the cartridge powder, leaving just enough room at the top for your bulb filament and match-head ignition device.

Wrap the top of the cylinder with electrical

tape and perform one final test with your VOM. Depending on how much black powder you used, it is best to detonate this device from a safe distance and from behind cover. Construct and test at least five of these devices before you deploy one in your homemade demolitions charge to ensure that you have mastered this useful technique.

To detonate this cap, you simply apply the proper voltage to the two wires. These devices are not sensitive to static charges because of the relatively high current required to detonate them. The improvised cap can be used to detonate pipe bombs as well as most improvised fertilizer-based charges when used with sufficient black powder. The device can also be used with most flammable liquid explosive devices as well.

With a bit of experimentation, other useful electrical detonation devices can be made from local materials. Most hobby stores sell model-rocket engine ignition wires, which can be used instead of the light-bulb filament to ignite the powder charge. A model-rocket-manufacturing company can provide these as well. One very well known firm you can contact for these devices is:

The Teleflite Corp.
11620 Kitching Street
Sunnymead, CA 92388

Appendix B

Recommended Reading List for Further Information

Subject	Source
Antenna Handbook Bill Orr W6SA1 192 Pages (#H145)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801
Antennas Tandy Corp. 127 pages (#62-1083)	Radio Shack
Basic Electronics Tandy Corp. 464 pages (#62-1395)	Radio Shack
Beginner's Guide To Reading Schematics Robert J. Trasiter 140 pages (#T215)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801
Easy Up Antennas Ed Noll W3FQJ 235 pages	Ed Noll P.O. Box 75 Chalfont, PA 18914

Electronics Data Book Tandy Corp. 155 pages (#62-1382)	Radio Shack
FCC Regulations U.S. Government	Government Printing Office Superintendent of Documents Washington, DC 20402
Getting Started in Electronics Forest M. Mims, III 128 pages (#276-5003)	Radio Shack
Landmobile and Marine Technical Manual Ed Noll W3FQJ 576 pages	Ed Noll P.O. Box 75 Chalfont, PA 18914
Radio Handbook Bill Orr W6SA1 1,168 pages (#S197)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801
Shortwave Propagation Handbook George Jacobs W3ASK 154 pages (#H137)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801
Semi-Conductor Reference Tandy Corp. 286 pages (#276-4011)	Radio Shack

Understanding Telephone Electronics Tandy Corp. 256 pages (#72-1388)	Radio Shack
Vertical Antenna Handbook Capt. Paul H. Lee N6PL 139 pages (#H208)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801
Vertical Antennas Bill Orr W6SA1 192 pages (#H303)	*Popular Communications* 76 N. Broadway Hicksville, NY 11801

Glossary

AC—Alternating current
AM—Amplitude modulation
Amps—Amperes; unit used to measure electrical current
AO—Area of operations
CB—Citizens band
CMT—Cellular mobile telephone
DC—Direct current
DEMO—Demolitions
DIP—Dual in-line package
DTMF—Dual Tone Multi-Frequency
ECM—Electronic countermeasures
FCC—Federal Communications Commission
FEAR—Field-Expedient Audio Modulated Relay
FM—Frequency modulation
HF—High frequency
KHz—Kilohertz
Ma—Milliamps
MHz—Megahertz
Ohms—Unit used to measure resistance of a device
PCM—Pulse-coded modulation
RC—Radio control; Remote control
RDF—Radio direction finding
RF—Radio frequency

RFI—Radio frequency interference
SF—Special Forces
UCW—Unconventional warfare
UHF—Ultra high frequency
VHF—Very high frequency
Volts—Unit used to measure electrical current
VOM—Volt-Ohmmeter

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